VOLUME 86 NO. HW2
JUNE 1960
PART 1

JOURNAL of the

Highway Division

PROCEEDINGS OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

BASIC REQUIREMENTS FOR MANUSCRIPTS

Original papers and discussions of current papers should be submitted to the Manager of Technical Publications, ASCE. Authors should indicate the technical division to which the paper should be referred. The final date on which a discussion should reach the Society is given as a footnote with each paper. Those who are planning to submit material will expedite the review and publication procedures by complying with the following basic requirements:

1. Titles must have a length not exceeding 50 characters and spaces.

2. A 50-word summary must accompany the paper.

3. The manuscript (a ribbon copy and two copies) should be double-spaced on one side of 8½-in. by 11-in. paper.

4. The author's full name, Society membership grade, and footnote reference stating present employment must appear on the first page of the paper.

5. Mathematics are recomposed from the copy that is submitted. Because of this, it is necessary that letters be drawn carefully, and that special symbols be properly identified.

6. Tables should be typed (ribbon copies) on one side of 8½-in. by 11-in. paper. Specific reference and explanation must be made in the text for each table.

7. Illustrations must be drawn in black ink on one side of 8½-in. by 11-in. paper. Because illustrations will be reproduced with a width of between 3-in. and 4½-in., the lettering must be large enough to be legible at this width. Photographs should be submitted as glossy prints. Explanations and descriptions must be made within the text for each illustration.

8. Papers should average about 12,000 words in length and must be no longer than 18,000 words. As an approximation, each full page of typed text, table, or illustration is the equivalent of 300 words.

9. Papers must be written in the third person.

This Journal is published quarterly by the American Society of Civil Engineers. Publication office is at 2500 South State Street, Ann Arbor, Michigan. Editorial and General Offices are at 33 West 39 Street, New York 18, New York. $4.00 of a member's dues are applied as a subscription to this Journal. Second-class postage paid at Ann Arbor, Michigan.

The index for 1959 was published as ASCE Publication 1960-10 (list price $2.00); indexes for previous years are also available.

HW,IR,WW.

Journal of the

HIGHWAY DIVISION

Proceedings of the American Society of Civil Engineers

CONTENTS

June, 1960

Papers

Journal of the
HIGHWAY DIVISION
Proceedings of the American Society of Civil Engineers

ANALYZING AND PROJECTING TRAVEL DATA[a]

By Wilbur S. Smith,[1] F. ASCE

SYNOPSIS

Projections of travel desires are essential for good transportation planning. This paper describes a comprehensive application of new techniques in a survey of the Washington, D. C., metropolitan area to determine the projections needed for planning a transportation system for the area.

INTRODUCTION

The Mass Transportation Survey of the Washington Metropolitan Area, completed in 1959, was jointly directed by the National Capital Planning Commission and the National Capital Regional Planning Council. The purpose of the study, which represented the efforts of many organizations and individuals, was to develop a future transportation plan for the area. The phase of the survey devoted to the traffic engineering study provides the basis for this paper. It involved an investigation of travel within the National Capital Region and was designed to correlate the generation of urban travel with future population, income, and employment throughout the urban community. Methods were developed to estimate the number, purpose, and distribution of trips which can be generated throughout the area.

Character of Metropolitan Area.—Estimates of future travel were made by applying new techniques to projections of population and land use in the Wash-

Note.—Discussion open until November 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Highway Division, Proceedings of the American Society of Civil Engineers, Vol. 86, No. HW 2, June, 1960.

[a] Presented at the October 1959 ASCE Convention in Washington, D. C.

[1] Wilbur Smith and Assocs., New Haven, Conn.

ington Metropolitan Area. This area embraces the District of Columbia, Montgomery and Prince Georges counties in Maryland, the cities of Alexandria and Falls Church, and the counties of Arlington, Fairfax, Loudoun and Prince William in Virginia. The District itself lies on the west central edge of Maryland along the Potomac River, which constitutes an important physical and psychological barrier to the free movement of traffic among Virginia, the District, and Maryland.

Past Growth and Trends.—Washington's early growth was slow but since World War II, the area's population has doubled, exceeding the national average growth for metropolitan areas. Most of this growth has taken place in the outlying areas, in Virginia and Maryland.

As the population has expanded and spread out, patterns of travel have shifted away from the use of transit to the use of automobiles. Of all employees depending on vehicular transportation to reach downtown Washington jobs in 1940, 42% used private autos. Today (1959), 70% drive to work.

Another trend is the increasing decentralization of government. Since World War II, there has been a rapid increase in both governmental and nongovernmental employment centers outside the district—notable examples being the Pentagon in Arlington County, Va., and the Bureau of the Census in Suitland, Md.

Future Growth.—The planner's view of Washington's future growth is one of rapid population increase and continued dispersal. The area population is expected to reach 3,000,000 by 1980, an increase of 91.3% over 1955. The total daily number of person-miles of travel is expected to triple by that time. The area's population trends are as follows:

Year	Population
1850	50,000
1880	180,000
1910	350,000
1940	1,000,000
1948	1,362,000
1955	1,568,000
1965	2,390,000
1980	3,000,000

Traffic and Transportation.—The street system planned by L'Enfant, and later extended beyond the downtown area, continues to carry the bulk of traffic moving in and out of Washington. A few freeways and parkways have been constructed in the area. However, the region does not have a "system" of free-flowing high capacity traffic arteries. Little of the mileage is in the central area where it is most needed and the few existing routes are, in large part, not interconnected.

Much transportation data have been accumulated in the National Capital Region during the past decade. Most important are two comprehensive origin-destination surveys conducted under supervision of the United States Bureau of Public Roads in 1948 and 1955. The perspective to be gained from a comparative analysis of these studies is enhanced by the numerous changes which took place between studies.

EXISTING TRAVEL PATTERNS

In both origin-destination studies, four separate surveys were conducted to obtain information from all segments of the traveling public. These included home, taxi, truck, and external interviews. The 1948 and 1955 data collected in these surveys were compared to identify general trends related to the passage of time.

Travel of all types increased approximately 50%, totaling more than 3,000,000 trips on a typical working day in 1955. The number of these trips made by auto drivers in 1948 was nearly 40%; by 1955, this percentage had increased to approximately 50%. About one sixth of the vehicle trips in the survey area were made by trucks in both 1948 and 1955. Many of these were made by heavy vehicles which contributed much more to traffic congestion than an equivalent number of passenger cars.

Despite the rapid population growth, over-all use of public transit declined approximately 17% during the 7-yr period. The number of taxi trips increased about 6%. However, the cabs in service in 1955 were about 15% more than in 1948, numbering nearly 10,000.

Approximately 7,000 commuters arrive and depart from Washington each day by three railroads and five intercity bus lines. Most commuter trips are for the purpose of work and are, therefore, made during peak hours. Persons arriving by railroad usually use transit or taxi to get to their destinations but most bus commuters walk from downtown bus terminals.

TABLE 1.—CAR OWNERSHIP AND USE

Year	Passenger Cars Owned By Area Residents	Average Internal Trips Per Day Per Car	Cars Per Thousand Population	Average Car Occupancy
1948	203,464	3.1	183	1.66
1955	418,497	3.1	266	1.56

Significant changes also occurred in modes of travel. The number of private cars owned by area residents more than doubled, increasing from 203,464 in 1948 to 418,497 in 1955, and resulting in a higher proportion of urban travel in cars. Car ownership statistics during the interim period are given in Table 1. Use of public transit declined from 677,960 trips per day in 1948 to 639,413 trips per day in 1955. Transit use increased only for school travel, from 48,652 daily trips in 1948 to 123,586 in 1955.

Profound changes were noted in the proportions of travel for commercial (business and shopping) and social purposes. Trips in the commercial category almost doubled, with most made by car. A distinct change in shopping hours was revealed, with a new emphasis on evening shopping. Home television and evening shopping in 1955 apparently cut into the time previously allotted to social travel. Social trips, including school travel, increased by only 25%. Excluding school travel, social-recreational trips actually declined from over 365,000 in 1948 to about 331,000 in 1955.

All trips were grouped into four main-purpose categories for each of the three principal modes of travel. Trips in the three most significant classes

have either origin or destination at place of residence. These "home-based" trips are classed as "work" trips, "commercial" trips and "social" trips. The fourth, or "miscellaneous" class of trips, is made up of "work" and "commercial" travel which does not begin or end at home.

These combinations were based on categories of land use, such as employment, retail sales, and population, so that relationships between land use and trip production could be determined and used to relate future travel to predictions of future land use. A comparison of trip purpose data from the two origin and destination studies is shown in Table 2.

Hourly Distribution by Mode and Purpose.—The principal purpose-of-trip categories have distinctive patterns of time distribution throughout the day. Since traffic congestion problems tend to be concentrated into a very few hours of the day, the significance of trip purpose and peak-hour travel can hardly be over-emphasized. The hourly patterns of travel in 1948 and 1955 provide the only available background for predicting the hourly distribution of work, commercial and social trips in future years.

TABLE 2.—PERCENTAGE OF INTERNAL TRIPS BY PRINCIPAL PURPOSE CATEGORIES

Mode Of Travel	Work		Commercial		Social		Miscellaneous		Total	
	1948	1955	1948	1955	1948	1955	1948	1955	1948	1955
Auto Driver	42.7	44.8	23.0	29.6	20.2	13.8	14.1	11.8	100.0	100.0
Auto Passenger	30.9	34.3	18.5	24.7	45.8	34.0	4.8	7.0	100.0	100.0
Transit	57.4	55.2	16.9	15.5	20.0	24.8	5.7	4.5	100.0	100.0
Total	46.3	44.8	19.3	24.4	26.0	22.3	8.4	8.5	100.0	100.0

The hourly distribution of auto trips was similar in both years. In 1948, the morning peak occurred between 7:00 A.M. and 8:00 A.M. The volume was slightly less in the hour from 8:00 A.M. to 9:00 A.M. In 1955, the reverse was true, with the morning peak hour coming between 8:00 A.M. and 9:00 A.M., representing a higher proportion of the day's travel than did the 1948 peak.

The evening peak occurred between 5:00 P.M. and 6:00 P.M. in both years, the 1955 peak again representing a higher share of the 24-hr volume. Midday travel was a smaller proportion of daily traffic in 1955, balancing the increased sharpness of the peaks. "Work" trips and "social" trips reached a peak together in the morning; in the afternoon, "social" trips were concentrated at 3:00 to 4:00 and "work" from 5:00 to 6:00.

Trip Generation.—The origin-destination studies showed that trips made by people who live in each district were related to income level, car ownership, and degree of decentralization (distance from the center of the metropolitan area), modified by the relative "isolation" of districts in the outer fringe of urban development. Fewer than 9% of all trips made by respondents to the home-interview surveys did not begin or end at home. Correlations were developed, using graphic techniques, to predict the average volume of trips made by residents of the districts for both 1948 and 1955 conditions.

Internal person trip-ends produced in the study area increased from 3,740,000 in 1948 to 5,090,000 in 1955 or 36.1%. The number of internal person trips generated in the central business district increased as follows: auto drivers from 114,117 to 284,052 or 148.9%; auto, truck and taxi passengers from 81,922 to 159,333 or 94.5%; and transit riders, from 272,372 to 321,941 or 18.2%.

The fact that the majority of families in most districts owned one or more cars was significant indication of the flexibility with which residents were able to move about the city and accounted for the high and relatively uniform rate of trip production by families throughout much of the study area. Toward the center of the city, transit facilities provided an efficient mode of travel which was used most extensively by lower-income families who live in the areas best served by transit and who own relatively few cars.

Analysis of automobile travel for each of the principal purposes showed the average number of persons riding in cars to be related to the level of car ownership (work trips) or related jointly to car ownership and decentralization (commercial and social trips). High-ownership areas (2.5 to 3.0 persons per car) averaged about 1.35 passengers per car, including drivers. Average occupancy rates were higher in cars from districts of low car ownership.

Method of Projection.—The method usually employed for projections of future travel, in which the patterns of travel recorded in an origin-destination survey are increased or decreased by growth or change factors, was considered not applicable for the Washington study. Since new land uses are expanding the areas of urbanization at a very rapid rate and travel information must be developed for a much larger area than that covered by the 1948 and 1955 origin-destination surveys, a "synthetic" or "interactance" technique was developed which relates the distribution of trips between districts to trip length (travel time) and the concentration of trip attractions (jobs, people, stores, etc.).

The formulas prepared for this purpose produced estimates of trip-rates between districts, avoiding the exaggerations and omissions in the original interview data by combining and averaging trips according to length. The formulas are related to district populations and travel times, rather than a fixed pattern of trips, and can be applied with equal efficiency to the original grouping of districts or to an expanded and redefined study area.

The formulas for synthesizing inter-district travel patterns are especially sensitive to time-distance relationships. The effects of highway and transit improvements in changing and realigning present patterns of travel can thus be predicted. Care must be taken to develop inter-district travel times which are realistic and consistent with the operational characteristics of new transportation facilities.

The Interactance Formula.—Trips which terminated outside the district of origin accounted for 80% of all travel in the region in 1955. This was travel that used arterial streets and public transit and which would realize substantial time savings and other economic benefits if improved transportation facilities were made available. The distribution patterns of this travel were very significant. The shortest movements were the heaviest. Most trips in the city were no longer than they had to be to accomplish the purposes for which they were made. Work trips generated by residents of a district were of short average length if there were many work opportunities within short range. Trips averaged much longer in suburban communities which were some distance removed from principal sources of work. The same was true of trips in each of the other purpose categories.

It has been found that the volume of travel between cities and towns was roughly proportional to the size of each community and inversely related to the distance between communities. These relationships were consistent and readily predictable.[2,3,4] Trips made between parts of an urban area have also been found to "interact" in a similar way to distance and trip attraction. The best correlations can be obtained if trips are segregated by purpose and an interactance formula derived from the specific populations (labor force and employment for instance) which account for the generation of each kind of trip.

Trip length is a critical measure in studies of the interactance effects. Within urban areas, trip length may be expressed in miles (either "airline" or actual land miles) or in terms of travel time. Travel time provides a better expression of relative distance between areas because speed of travel varies a great deal on different kinds of roads and in different parts of a city.

Travel times by car and by transit were compiled for peak hour and off peak conditions throughout the region and studies were made to find which was best suited for trip analysis. Correlations obtained using off peak driving time were found to be better. Even work trips, which are predominantly peak hour movements, were described better by off peak time measurements.

Trips between pairs of districts were expressed as "trip rates" to relate them to trip length. Units of populations, labor force, or employment were divided into volumes of interdistrict trips to develop average rates (trips per person, trips per labor force, trips per job). In the case of commercial trips, trip rate was stated in terms of trips per dollar of retail sales, or trips per 1% of metropolitan area sales.

When trip rates were plotted against distance, the "interactance" effect was depicted in the form of a decay curve. The shortest trips did not necessarily produce the highest values on the curve, however, because the origin-destination data did not represent all of the travel between districts. Many very short trips were made on foot and were not recorded in the study. The high point on the curve occurred where walking trips were no longer important (5 min to 6 min driving time).

A series of multiple correlation equations were developed to describe the average generation of truck trips in districts in Washington, based on 1955 data. Employment, retail trade, and population were elements of the formulas.

Government and non-government employment were evaluated separately. Most government work did not involve transportation of goods. Much non-governmental work, excepting the central business district, was closely related to goods' handling and industrial production which created a high demand for trucks. The demand for trucks was also high in retail centers.

FUTURE TRAFFIC

For purposes of traffic analysis in 1948, a cordon was drawn around a population of approximately 1,110,000 persons. For the 1955 origin and destination study, the cordon was extended slightly, surrounding a population of 1,570,000.

---

[2] "The Law of Retail Gravitation," by William J. Reilly, 2d Ed., M. Pilsbury Publishers, Inc., New York, N. Y., 1953.

[3] "Sociological Relationships of Traffic to Population and Distance," by Fred Charles Ikle, Traffic Quarterly, April, 1954.

[4] "Evaluation of Inter-City Travel Desires," by Willa Mylroie, Highway Research Bd., Bulletin 119, Washington, D. C., 1955.

A new cordon line was drawn to define the area which will contain the expanded urban community in 1955 and 1980. This cordon includes within it more than three times the area contained within the 1955 cordon. The population projected for the area within this cordon in 1965 is about 2,239,000 persons, or 470,000 more than were in the area of study for 1955. By 1980, the new cordon would encompass a population of approximately 2,720,000 persons, an increase of more than 70% over the population in 1955. Projections were made of the probable locations of future employment and commercial centers, using values that planners have projected.

Controlling Factors.—In analyzing the trends between 1948 and 1955, it was shown that the lower income families experienced a greater increase in over-all trip production in that 7-yr period than did the upper income families whose average trip production changed very little. It is likely that lower income families will produce more trips in 1965 and 1980, on a per-family basis, than at present. This assumes that the over-all economy of the region will continue to show an upward trend.

In developing minimum projections of mass transit trips to 1965 and 1980, the assumption was made that transit service available at those dates would be of the same quality as is currently offered by public transit in the city.

TABLE 3.—PROJECTED RATIO OF CARS TO PEOPLE

Year	Urban Population	Cars Owned	Population Per Car
1948	1,109,860	203,460	5.46
1955	1,569,308	418,500	3.75
1965	2,238,600	668,180	3.35
1980	2,720,700	897,000	3.03

Car ownership will continue to increase in the region. There is evidence, however, that there will be a leveling off. In 1955, car ownership in many districts approached what appears to be a saturation level. Most of the expected new populations will be located in the suburbs and will, therefore, be heavily dependent upon the car, especially in the early stages of suburban development. This means that as the area between the 1955 and 1980 cordon is settled, the districts are expected to exhibit near-saturated car ownership levels.

The projected ratios of cars to people are illustrated in Table 3.

Estimates of Trip Ends Generated in Each District.—The factors previously outlined furnished the basis on which estimates of future traffic demands in the region were founded. The estimates themselves were developed in two principal stages: (1) estimate of the number of trip ends generated in each district; and, (2) estimate of trip distribution between districts.

Estimates of the total number of trips generated in each district were based on the statistical data compiled for 1965 and 1980. The curves developed in the analysis of the 1948 and 1955 origin-destination surveys were applied directly to statistical projections to derive an over-all estimate of the number of trips that people would be expected to generate in the study area in 1965 and 1980.

Projections of trips to 1965 and 1980 included the expected new growth and assumed rates of car ownership and income levels consistent with recent

trends. As a result, the average generation of trips per person in future years is expected to be greater than in either of the origin and destination surveys. Internal travel by residents in 1965 and 1980 is expected to average 1.85 to 1.9 trips per person per day.

Within each of the four purpose categories, trip estimates were projected by mode of travel. A minimum estimate of transit riders was projected to 1965 and 1980. It was assumed that all remaining trips would be made in cars. Distinction was made between drivers and passengers. Although only the auto drivers would be significant in evaluating traffic on highways, both the drivers and passengers would be potentially divertible to transit if an improved form of public transportation were made available.

It was also found necessary to distinguish between transit-oriented travel and travel by automobile. Since a basic assumption was made that transit service would be identical in future years with that presently available, the curves developed in the analysis of the origin and destination surveys were applied directly to the conditions of car ownership, economic level and decentralization related to transit use.

Trip Distributions.—The analysis of 1948 and 1955 trips revealed that the pattern of travel by each mode and for each of the four basic purposes was distinctive. Work trips were of longer average length than trips for other purposes; commercial and social trips were of intermediate length; miscellaneous trips were the shortest.

The "interactance" curves were applied to control totals for each of the three principal modes of travel in each of the four purpose classifications. When applied directly, the curves produced "relative" numbers of trips which represented average conditions. Trip estimates produced from the average curves were in correct proportions but may not have developed appropriate volumes. Trip estimates for each district were adjusted by summing them and dividing the sums into the control totals to produce a correction factor. The factor, applied uniformly to trip estimates for each district, produced an adjusted trip total equal to the control total.

Estimates of Travel at External Cordon.—The number of automobiles in the region has increased at about the same rate as external travel. Auto ownership also increased very rapidly in all of the external communities which contribute to traffic at the cordon. It is, therefore, reasonable to expect that traffic at the external cordon will change in proportion to changes in automobile registrations.

Estimates of external auto driver trips at the cordon were made for 1965 and 1980 on the basis of the car ownership projections. Trip increases at each of the ten station groups were computed separately.

Estimates of Future Taxi Travel.—Suburban taxi fleets increased considerably from 1948 to 1955, and will probably continue to grow. Many other conditions which have fostered the development of taxi service seem destined to expand. Increasing air travel should create more demand for taxis. Expansion and decentralization of government functions will require more travel by nonresidents visiting the region on business.

Projections to 1965 and 1980 have been made by applying 1955 rates of trip production (trips related to attraction units) to 1965 and 1980 populations. Taxi trips were projected to 1965 in about 20% larger volumes than in 1955, and 1980 travel was increased by about 35%.

Estimates of Future Truck Travel.—Within the central business district, the generation of truck travel was related directly to the percentage change in

employment, retail trade and population. The number of trips reported in 1955 was increased, or decreased, in proportion to the weighted change in trip generating potentials within each district.

Inter-district truck trips were next distributed between district pairs according to the interactance curve. This work was done on a high-speed electronic computer, the UNIVAC. The first approximation of inter-district travel was prepared by applying values from the curve to trips generated in each district. First approximations were then averaged and balanced through four successive iterations.

The volume of external trucks at each station group was projected to 1965 and 1980 at rates consistent with population growth within the cordon. Increases in truck travel were not expected to be as great as auto travel, according to trends from 1948 and 1955.

Barriers to Travel.—The Potomac River is a major barrier to the free flow of traffic in the study area. Bridges across it are located centrally, so that there is real restraint on travel between areas which may be close together physically, but far apart by way of the bridges. In addition, there are other barriers such as the National Airport, the Pentagon, Arlington Memorial Cemetery, and the riverfront parkways.

The history of new bridge construction shows that no new bridge has been built until traffic on other bridges exceeds the available capacity at peak hours.

Projections to 1965 and 1980 assumed several new crossings. These were expected to accommodate traffic without congestion as part of the freeway system. The crossings on the highway system are the only new river crossing facilities to be provided in the future. Throughout the rest of the urban community the expressway system supplements a very extensive network of local streets which, for many trips, provide more attractive service than the projected freeways.

It does not appear realistic to expect that future travel will be completely relieved of the trans-river barrier effect. The rates of travel by internal residents (auto drivers and passengers) across the Potomac River were therefore reduced by approximately 30% in the 1965 and 1980 projections. River crossing trips thus deleted were pro-rated to inter-district travel which did not cross the Potomac. Trips in each purpose category were treated separately. No other adjustments were made in projecting travel patterns across physical barriers, since travel across the Anacostia River was not so centrally concentrated as at the Potomac, and trans-river travel, as measured, seemed to conform to trip rates developed in the interactance formulas.

Total Travel Desires.—As shown in Table 4, total person trips in the area (exclusive of truck and taxi drivers) numbered 4,930,000 trips in the 1965 projection and 6,070,000 in the 1980 projection, an increase of 87.7% and 131.1%, respectively, over the value for 1955. Work trips are expected to make up about 42.5% of all personal travel in the area by 1980. About two thirds of these trips will be made during the 4 hr of heaviest travel during the day.

In developing trip projections to 1965 and 1980, correlations were found which describe the production of trips in terms of significant variables such as income level, car ownership, the relative isolation of population in each district, and travel time from the central business district. The curves and formulas which illustrate these relationships represent average values for the conditions studied.

While some of the predictive formulas represent the interactance of several of the chosen variables, it must be recognized that travel within the re-

gion is made in response to an almost infinite variety of motives and is performed by the most readily available means. The few variables to which travel data were related reflect the gross patterns of these many movements.

These trip projections may be considered representative of travel within the region at dates when the population has reached 2,400,000 persons (about 1965) and 3,000,000 persons (about 1980). Estimates of travel generated in each of the relatively stable districts inside the 1955 cordon line should be well within 10%, more or less, of the travel which will actually develop. The same may be expected of the other districts, provided that land-use developments conform to planners' projections.

Estimates of travel between districts are subject to considerably more variability than estimates of total trip production because so much depends on the quality and capacity of highways and transit facilities which link districts together. If these improvements were to fall short of the systems on which trip patterns were predicated, other patterns would result. Fewer long trips would be made, with considerable reorientation of the travel generated in districts toward the periphery of the study area. On the other hand, the highway

TABLE 4.—TRAVEL DESIRES IN 1955, 1965, AND 1980

Type Trip	1955	1965	1980
Person Trips to and from Central Business District	883,469	1,340,000	1,500,000
Trips Between Districts Excluding Central Business District	1,743,036	3,590,000	4,570,000
Taxi Trips	266,654	-	362,000
Truck Driver Trips	277,028	-	681,000

system proposed by the civil engineering consultants is more extensive than the plan upon which travel patterns were based. This plan, if completed at an early date, would encourage the production of a greater number of long trips, provided the system could operate without serious congestion. It is important, therefore, that a continuing study be maintained to re-examine and modify these trip projections from time to time as the transportation system grows.

EVALUATIONS OF THE TRANSPORTATION SYSTEMS

As part of the over-all survey to determine a transportation plan for the area, the assumption of four alternate systems was made by local and regional planners. Since these systems are basic to the over-all study, there will undoubtedly be some duplication.

One of the basic purposes of the traffic study was to develop trip projections for 1965 and 1980, as already discussed. Another phase was the testing of the various transportation plans through traffic assignments to them.

Transportation Systems.—Trip assignment estimates were applied to the following four transportation plans:

I.—The auto-dominant system which would consist of an extensive network of freeways, parkways and arterial streets together with large-scale downtown parking facilities.

II.—The express bus system which would consist of high-speed buses making few stops and traveling on the extensive network of freeways and parkways, or on their own grade-separated lanes.

III.—The rail or other train-type transit system, also operating at high speeds and making few stops, which would be on grade-separated rights-of-way located either in the center mails of radial freeways, or on other exclusive rights-of-way.

IV.—The information obtained from these three basic study plans was used to formulate a recommended transportation plan to facilitate the optimum movement of people and goods in the National Capital Region, and to which final traffic assignments were made.

Sequence of Assignments.—Traffic assignments to the several transportation systems consisted of three distinct sequences. Preliminary or exploratory assignments were made to a 1980 auto-dominant highway system (Plan I) and to four combination highway-transit systems, including an all-bus system (Plan II) and three variants of a train-type system (Plan III). This developed the over-all magnitude of the future transportation problem.

Revised assignments were then applied to optimum systems of highways and improved transit. The highway plan consisted of 530 route miles of limited access facilities to which auto-dominant assignments were made, using both 1965 and 1980 trip projections. Two comprehensive transit plans were also analyzed, including an all-bus system and a train-type system, developing maximum 1980 transit assignments on the assumption of minimum new highway improvements.

Assignments were finally made to balanced integrated systems of highways and transit. Assignments were made to about 305 route miles of limited-access highways by scaling down estimates of use on the maximum system, balancing between local street capacities and assumed design standards for each segment of route. Assignments for 1980 were developed in conjunction with an all-bus transit system and a train-type transit system. A combination bus-rail transit system was also developed by the civil engineering consultants and balanced highway-transit assignments prepared for 1965 and 1980 trip projections.

Preliminary Trip Assignments.—Preliminary assignments were all-day (24-hr) estimates of use on highway and transit systems. Revised assignments and balanced assignments consisted of peak hour and 24-hr estimates of use on each section of highway and 24-hr estimates of transit use. These data were converted to design-hour values by the civil engineering consultant.

All of the analyses were related to the future urbanized area within the 1965-1980 external cordon. Trip assignments were made to "traffic corridors" to develop the relative magnitudes of travel demand throughout the study area.

Assignments between local streets and freeways and assignments between streets or freeways and improved transit were based on time-ratio curves. Travel times for automobiles are usually on-street running times between the centers of trip-generating areas. In addition to actual time in travel, allowance was made for parking and walking time at either end of the trip; 10 min were added to travel time for trips which began or ended in the central business district and 5 min were added to driving time for trips with neither end in the central business district.

Travel times on express highways were computed between points of entrance and exit. Travel times between access points and district centroids were computed at city street speeds. Local transit travel times were compiled from route schedules. Travel times on each high-speed transit route were computed from assumed operating speeds.

Trip time via express bus or rapid transit was divided by auto travel time via streets or express highways to obtain factors for estimating diversion from auto to transit if a superior system of public transportation were made available.

In the assignment studies, certain variable conditions other than travel time were considered for the influences they might have on mode of travel. These factors were either balanced, or were evaluated by weighting the travel-time factor: out-of-pocket costs via highway and transit were assumed to be equal; standards of comfort on improved public transportation facilities were considered equal in all respects to travel by private car; time consumed in waiting for transit vehicles, parking cars, and walking between car or transit stop and actual terminus of trip was considered part of the portal-to-portal trip time.

Trips Assignable to Highways and to Transit.—All of the projected vehicle trips were assigned to streets and highways in Plan I. These included internal auto and taxi drivers and external auto drivers. (Truck trips had not been projected at the time preliminary assignments were made). The time-ratio (express highway time/local street time) was computed and factors applied to travel between district pairs to determine the number of trips to assign to freeways.

The number of vehicles assigned to streets and highways in Plan I was reduced in Plans II and III because some vehicle drivers were diverted to transit. All auto driver trips, made by area residents who were not considered to be auto-oriented, were assigned to either highways or transit, depending upon the travel time advantage.

About half of the taxi passengers were considered to be oriented to the use of taxis. Among the remaining passengers, some could be assigned to transit.

Several types of travel were assignable to express buses, or to rail rapid transit. Transit-oriented trips projected to 1965 and 1980 as "minimum" estimates of transit use were the most important category of divertible trips. This travel was already assigned to transit. If faster service became available, most riders would transfer to the new and improved facilities.

Analysis of Preliminary Assignments, 1980.—Analysis of the 1980 preliminary highway assignments indicated that very large volumes of traffic would seek to use the network of freeways and dualized arterial streets proposed for construction by 1965. The traffic volumes potential to many portions of the system indicated that a more extensive system of highways would be required to accommodate all of these demands.

The assignments to express bus and rail rapid transit systems showed that the number of trips potential to faster transit in the most heavily traveled corridors appeared to be large enough to justify further study of rail or other train-type rapid transit.

Revised Trip Assignments, 1980.—Procedures for trip assignments to the revised transit and highway systems were modified to provide more complete information than was obtained in the preliminary studies. Separate peak-hour and off-peak trip assignments were made, with emphasis on design hour requirements.

The maximum assignments of travel to highways and transit were developed in an orderly sequence, based on the assumptions stated previously. These assignments indicate the relative demands of travel on the various systems of transportation that were studied. On the other hand, their theoretical nature makes them unsuited for the design of either a highway or a transit system without further adjustment.

For instance, there are practical limitations on the number of lanes that can be built into a single highway. It was agreed that an 8-lane freeway represents a practical maximum size for highway facilities in the National Capital Region, due largely to problems of ingress and egress from highways of more than 8 lanes. The theoretical highway assignments produced design-hour loadings far in excess of 8 lanes at several points in the system.

Transit potentials were also over-optimistic in the maximum assignments because it is extremely unlikely that new highway construction will cease when the roads presently programmed have been built. The maximum transit assignments did not reduce corridor demands sufficiently to eliminate the need for new highway construction, but they did result in need for fewer lanes of highway in some corridors.

In analyzing assignments, it was necessary to differentiate between volumes that might be desirable in design and volumes which are likely to occur under typical operating conditions. According to present design standards, it is desirable to think in terms of average lane volumes of from 1,200 to 1,500 vehicles per hr on freeways. Under operating conditions, average lane volumes at peak hours of 1,800 to 2,000 vehicles per hr are common in large cities. However, under certain conditions and for shorter periods, actual lane volumes in operation have been found to be even higher—up to 2,300 vehicles per lane per hr.

Naturally, it would be highly desirable to provide roadway facilities that even under periods of peak demand would not carry volumes in excess of 1,500 vehicles per lane per hr because this would permit a high degree of safety and a very attractive level of steady flow. Conversely, when facilities are available, it must be expected that they will be utilized and that heavier operating volumes will be found during the peak demand periods. Attempts to prevent the higher volumes would be criticized and it is doubtful that public reactions would permit any drastic controls being applied for sustained periods. If the volumes shown by the assignments are looked on as "operating volumes," they take on much more realistic proportions than if they are looked on merely as "design volumes" or as "ideal volumes."

Balanced Highway Plan and Transit System.—After careful study of the auto-dominant highway plan, the civil engineers prepared another plan limiting freeway designs to no more than 8 lanes, and supplementing freeways in most corridors with local street widenings, extensions and other improvements. This plan assumed the development of a modern transit system to complement the new freeways.

Projected trips were summarized for the auto-dominant highway system with no improved transit, and for the balanced highway system with improved transit.

At the hour of heaviest travel on an average weekday morning in 1955, 105,000 persons arrived in the central business district by car and another 55,000 persons utilized transit. If it is assumed that public transportation will remain basically the same in the auto-dominant system, some 120,000 persons would be

expected to arrive in the central business district in cars in the peak hour in 1965; these would increase to 140,000 at the peak hour in 1980; about 50,000 transit riders would arrive downtown in the peak hour in either year. If the recommended transit system is built, the number of persons arriving in cars would be reduced to 100,000 and local transit would carry about 15,000 in both years; passengers using rapid transit would number about 55,000 in 1965 and 75,000 in 1980.

In 1955, nearly 2,500,000 trips were made in cars and 640,000 trips (20.4% of the total) by transit. Without improved transit, 4,085,000 trips would be made by car in 1965 and 845,000, or 17.2% of all trips, by transit. By 1980, cars would account for 5,205,000 trips and transit 865,000, or 14.3% of 24-hr travel. With transit improvements, express and local transit would account for 1,115,000 trips per day, or 18.4% of the day's total by 1980. The recommended rapid transit system would carry 57% of all transit users in 1965 and 68% in 1980.

As pointed out, the traffic study on which this paper is based was a part of the over-all Mass Transportation Survey of the Washington Metropolitan Area. All data are available in graphical form.[5]

SUMMARY

The traffic studies reported here represent one of the most exhaustive analyses of urban travel ever undertaken. The disciplines of city planning, sociology, economics, and civil engineering have been coordinated with traffic engineering technology to produce a broad-based study of traffic generation and transportation needs which has been used to guide and evaluate several possible transportation plans for the nation's capital city.

While we recognize that the growth and development of the Washington area will probably not be in accord with every detail of the conditions assumed in these studies, the basic relationships of traffic to the Washington environment have been drawn with considerable accuracy and are reliable. Unless future growth departs radically from that envisioned by the urban planners and others associated with the study, the direction and magnitude of tomorrow's traffic problems will bear a sharp resemblance to the conditions set forth in this study. The requirements of a sufficient and satisfactory transportation plan have thus been defined.

---

[5] "Traffic Engineering Study, Mass Transportation Survey, National Capital Region, 1958," by Wilbur Smith and Associates.

Journal of the

HIGHWAY DIVISION

Proceedings of the American Society of Civil Engineers

CORRELATION OF VEHICLE DESIGN AND HIGHWAY DESIGN

By Richard A. Haber,[1] F. ASCE, and David K. Witheford,[2] A. M. ASCE

SYNOPSIS

Past and present developments in the highway field indicate that insufficient coordination of vehicle design and highway design is placing the highway program in a precarious position. Current highway expenditures and those contemplated for the future represent an investment that must be protected. The situation calls for a unified research approach supported by industry and all interested groups and agencies.

INTRODUCTION

Denouncing the auto industry for the production of long, low, flashy, finny monsters of questionable design has become a favorite after dinner sport. At the same time many people revel in their new prestige as owners of "nice little foreign cars which invoke feelings of owning a finely machined piece of Old World Craftsmanship." Is this thought pattern a trend which will be met by the growth of American-made, compact cars? Have economies in cost and operation become essential to design criteria? Or is the "compact car" considered by manufacturers a backward or side step in the competitive race to a new sized, "automated" family vehicle of the future? Some hints concerning the vehicles of the future have been offered. The development of controls to be used in them is in process. It is not strange that the entire subject lends itself to conversational speculation, by highway engineers as well as the public.

Note.—Discussion open until November 1, 1960. To extend the closing date one month, a written request must be filed with the Executive Secretary, ASCE. This paper is part of the copyrighted Journal of the Highway Division, Proceedings of the American Society of Civil Engineers, Vol. 86, No. HW 2, June, 1960.

[1] Chf. Engr., Del. State Highway Dept., Dover, Del.

[2] Planning Engr., Del. State Highway Dept., Dover, Del.

No less popular is the perpetual subject of taxes, and whether the American taxpayer is receiving services commensurate with the funds he is providing. Signs of this thinking are obviously behind the current investigations of the highway program initiated by the White House and Congress. The present delays to highway progress are perhaps due in part to a lack of official confidence in our ability to plan properly, build well, and spend wisely the public funds that have been provided.

Highway engineers and builders do not have this lack of confidence and have expressed confidence in their ability to do the job. They should not rest on this belief and fail to guard against these factors that lead to charges of inefficiency and waste in the use of public funds.

Possibly the most important factor contributing to imagined and real waste of highway funds is untimely obsolescence. All highway engineers have seen examples of highways costing millions of dollars rendered inadequate by unpreventable right-of-way development, necessary traffic controls, or traffic volumes rising beyond all expectations. Highway engineers have developed measures to apply against these defects, such as access control, grade separations, and more refined traffic forecasting techniques. There is, however, another less obvious and more insidious cause of highway obsolescence; one over which the highway industry has little influence. It stems directly from the characteristics of the vehicles using the nation's highways.

The objective here is to outline what has happened to highways because of changing vehicle characteristics. The purpose is to urge the development of a unified approach by the motor vehicle designers and the highway engineers to their inseparable problems. The need for such correlation has been present for the past 50 yr. This need has been met partially, and with reasonable success. If it had not, today's highways would be even more inadequate. But, with problems increasing because of the massive highway program, efforts must also increase to achieve optimum highway value.

It is vital that a greater measure of communication between vehicle designers and highway designers be put into action, without sacrificing the creativity of either group by the establishment of unnecessary controls.

Why is this need so acute at the present time? The answer is obvious. The trend to larger and heavier commercial vehicles is more apparent than ever. In addition, expenditures for highway improvements are at their highest level in history. That they will continue to increase in the years ahead is generally accepted. The challenge is in the present and future but the past contains the lessons. It is worthwhile therefore reviewing what has happened in the past. The year 1927 is a good place to begin.

BASIC PHILOSOPHIES

By 1927, both the automobile and its routes of operation had been on the public scene long enough for philosophies to have been crystallized by the respective interested groups of vehicle manufacturers, highway builders, and the public. Examination of these philosophies reveals the fundamental reasons for the divergence of viewpoint that existed then even as today.

The basic principles of free enterprise and competition govern the manufacturer's outlook. His tools and plants are built with private capital which demands a maximum cash-in-hand return on the investment. His products must compete with those of other manufacturers for the private "convenience capital"

of the consumer. In a larger sense, the vehicle manufacturer is also competing with other forms of transportation in an effort to broaden his markets. Consequently, frequent, detailed, design changes have become necessary to meet competition. The result is that each end product has a relatively short-lived appeal and is annually replaced by something hoped to have an even greater public appeal. This accepted manner to provide the maximum return on capital investment, has been labeled "planned obsolescence."

On the other hand, the highway administrator is governed by legislative bodies which establish funds and procedures for his operations. For example, the law establishing the Delaware State Highway Department in 1917 required that highways should be designed for a 40-yr-life. In any case, the fact that the highway engineer draws on "involuntary receipts" (commonly called taxes) for capital expenditures requires him to design for long use, with economy in construction and maintenance as co-equal principles. The capital investments are non-recoverable, except in terms of the service provided users and non-users. These considerations are a major influence toward economical design.

The road-user provides funds through taxation for the highway system. He also provides income for the manufacturers by purchasing their products. Although the individual may feel that he is being pushed and pulled continually by both groups, the fact remains that he is the one who establishes the directions taken by the other two.

Inevitably and understandably, the road user dislikes being taxed for services if dubious about the measure of service provided. He demands that his tax dollars yield maximum benefits. This sometimes leads to contradictions, depending on whether he is sitting behind the wheel or behind the chairman's desk at a civic association meeting. When making a voluntary expenditure, he wants the most for his money. In the case of passenger vehicles, this has been interpreted to mean that cars must become longer, wider, more powerful, more comfortable, and more "stylish" (which has been achieved partly by lowering height to give apparent greater length).

In commercial highway transportation, economy of operation is critical. This has been obtained in part by making each unit capable of hauling heavier loads at greater speeds. Although the operator realizes this economy, he also necessitates a relatively greater use of tax dollars to accommodate such units.

Admittedly, this has been an over-simplified statement of controlling influences, but is, nonetheless, relevant to the following outline of vehicle and highway design development.

VEHICLE DESIGN DEVELOPMENTS

The technological skills and creative imagination of the American automotive industry cannot be doubted. Its ability to produce vehicles of high quality in vast numbers at low cost has earned worldwide respect and envy. But the pace of development in this industry has caused many of the problems in the highway profession. Some of the changes in design are shown in the accompanying figures and tabulations. An expression of debt must be included here to the researchers in both industry and public service who have compiled these figures.

In connection with passenger vehicle characteristics, it can be seen from Fig. 1 (a) the average lengths of 4-door sedans have increased since 1927 by 46 in. In the so-called, "low priced three," the length change has been 60 in. Average widths during the same period, shown in 1 (b) have increased slightly

over 11 in. to the present 78 in. The effective width change for parking purposes, is actually greater since the doors have been moved outward to the fender line. As shown in Fig. 2. The only dimension which has decreased has been height. It has dropped from an average of 73.7 in. to 57.4 in., a reduction of 16.3 in. Data on angles relating to the underclearance of passenger vehicles are illustrated in Fig. 3 and show the trends since 1948. The angle of approach which averages 21°, with a minimum sample at approximately 14°, has not changed. However, the mean angle of departure has decreased from 16° to a fairly stabilized level of 12° to 13°. The minimum angle of departure was 9° in 1959. The ramp breakover angle has decreased from an average 16° to approximately 11°,

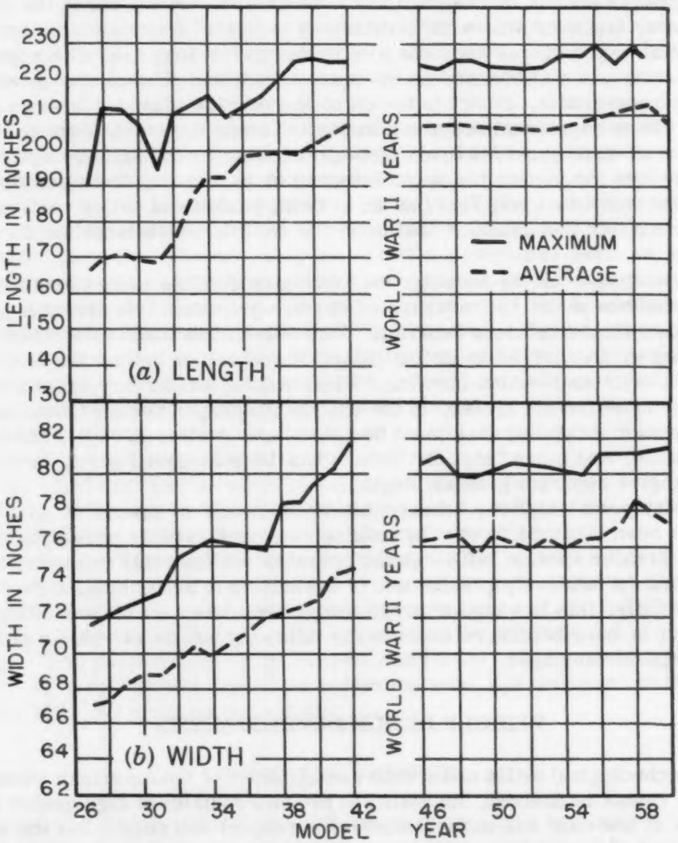


FIG. 1.—LENGTH AND WIDTH OF 5 TO 6 PASSENGER, 4 DOOR SEDANS

with a 1959 minimum of 7 1/2° on one American-made sports car. There has been little change in ground clearance, averaging just under 6 in. for all models, with a minimum of 4 in. The figures relating to underclearance do not take into account conditions of "jounce" or spring compression, that further reduce the angles or clearances in dynamic situations. Nevertheless these figures are meaningful to those concerned with the abrupt grade changes that occur at ramps and driveways.

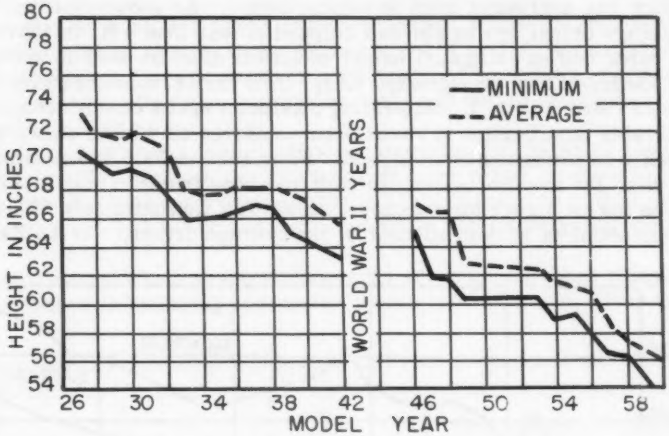


FIG. 2.—HEIGHT OF 4 DOOR SEDANS WITH 5 PASSENGERS

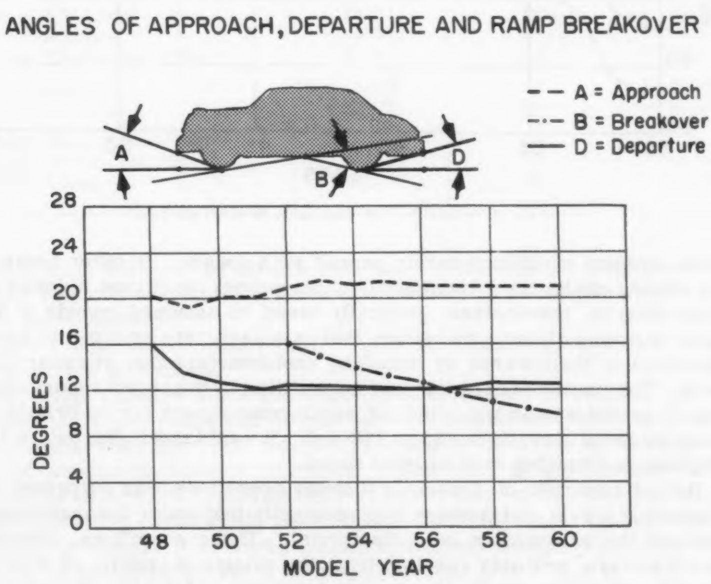


FIG. 3.—VEHICLE CHARACTERISTIC TRENDS

The passenger vehicle dimension of greatest concern to the highway engineer and which has decreased most is vehicle height. As shown by Clyde E. Lee[3]. The average driver eye height had dropped to less than 4 ft. in 1957 and later model cars, and an estimated height of 3.95 ft must be used to accommodate 85% of the drivers on the highways today. This factor, combined with the speed increases noted in Fig. 4, illustrating maximum speed capabilities, results in considerable modification to vertical curve design-as will be shown later.

Speed is an absorbing topic in itself. From 1930 to 1955, the maximum speed potential of the average American built car rose from 66 mph to 97 mph. In 1955, the lowest figure for maximum speed was approximately 80 mph. This speed potential is seldom utilized by the average driver. On the East Coast,

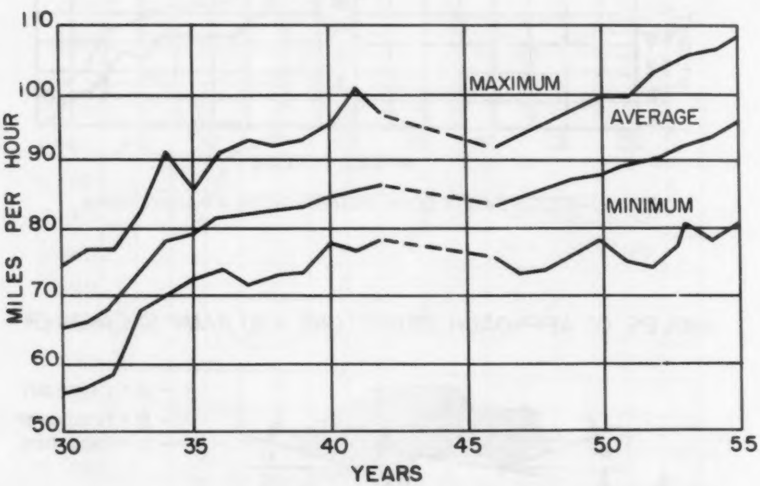


FIG. 4.—TREND OF MAXIMUM CAR SPEED

at least, highway conditions rarely permit such speeds. In other areas where higher speeds can be maintained safely under proper conditions, highway design and operation is, nonetheless, generally based on assumed speeds of 70 mph or less. It seems strange, therefore, that manufacturers continue to advertise the potential of their wares by installing speedometers that register 120 mph or more. The consequence of this was exemplified by the recent report concerning the 60 yr-old woman who tried out her German sports car on Britain's first freeway, to see if it really would go 140 mph. It would and it did, before leaving the highway and turning over several times.

A British observer of American freeway operations was surprised to find that "speed of travel on freeways is consistently just under the maximum permitted and the remarkable lane discipline". These conditions, observed on Detroit freeways, probably resulted from the volume of traffic, as well as reflecting the effectiveness of enforcement practices and driver education. They possibly also reflect, under certain circumstances, a public awareness of the need to resist the inducements to speed offered by the vehicle manufacturers.

[3] "Driver Eye Height and Related Design Features," by Clyde E. Lee, The Univ. of Tex., Bur. of Engrg. Research, Austin, Tex., 1959.

The claim has been made that the changes in size and speed potentials of passenger vehicles have been dictated by customer demand. Certainly these demands, if they exist, are based on the occasional maximum need of the user for passenger space, storage capacity, and speed of travel. The ingenuity of the industry in meeting these demands is remarkable. The sense of responsibility toward the obvious effects on highway systems and traffic operations has been somewhat less than remarkable.

Much more significant to the highway engineer is the change in commercial vehicles. In 1927, highway design standards were based on design speeds of 35 mph; most bridges were designed for H-15 loadings; bus widths were 8 ft; truck widths were 7-7 1/2 ft; and maximum gross vehicle weights were approximately 30,000 lb.

Comparable vehicle characteristics today show, among other items, a necessary increase in operating speeds for commercial vehicles. This has been accompanied, however, by official distrust of other operating characteristics, that has resulted frequently in lower speed limits than those that apply to cars on the same highways.

TABLE 1.—DIMENSIONS AND WEIGHTS ACCEPTED IN CURRENT AASHO POLICY.

Item (1)	AASHO (2)	No. of States Exceeding (3)	Maximum Allowed (4)
Width	96 in.	3	108 in.
Height	12-6 in.	30	No limit
Length - S U Truck	35 ft	18	42 ft
S U Bus	40 ft	29	55 ft
Tr. Tr. Semi Tlr.	50 ft	18	65 ft
Single Axle Load	18,000	31	24,000
Tandem Axle Load	32,000	29	40,000
Practical Max. Gross Weight			
4 Axle Tr Tr Semi Tlr	55,470	47	66,400
3 Axle Truck	40,000	27	52,000

Table 1 indicates dimensions and weights accepted in current AASHO policy, with pertinent exceptions.

The major changes since 1927 have obviously been in weights and lengths of vehicles, while widths and heights have remained relatively unchanged. It would appear that the truck manufacturers have been forced to follow design policies similar to those of railroads, whose fixed gauge, track spacing, and clearances in terminal facilities have required them to improve equipment and reduce operating costs within those limits. Since highways are, more or less, fixed assets similar to railroad trackage, highway design, within certain limitations, would certainly seem to be appropriate.

That this is not the case can be seen from recent developments, that indicate the continued trend to larger size and loadings. An example can be drawn from the New York Thruway, which now permits the operation of 100 ft long combinations with gross weights up to 130,000 lb. Motivated by a logical desire for increased freight hauling efficiency, both industry and users are

pressing for greater vehicle widths and lengths exceeding current AASHO policy (although still below some States' tolerances). Removal of restrictions on the number of units in combination, and increases in allowable single and tandem axle loadings are also desired. A composite picture of the suggested freight vehicle of the near future suggests a width of 9 ft, height of 13 ft 6 in., length up to 100 ft, and gross vehicle weight close to 200,000 lb. There are apparently no vehicle design problems that would prevent such development.

It has been noted that no major height increase is anticipated. Yet, the United States Department of Defense has requested a 17 ft clearance for structures on the interstate system. It is believed that not only will this be provided, but that it will result ultimately in requirements of greater clearances on other systems for both public and private vehicles.

Some reference must be made to other future vehicle developments. The air-supported vehicle that travels without ground contact has proved to be a practical consideration. It would certainly solve axle loading problems. An inherent requirement in its design is a smooth surface free of the fallen objects and debris which so frequently litter the highways. It is hoped that solutions to parking, driveway problems, and urban driving, are being considered concurrently with such designs. Other proposals have been advanced, incorporating fingertip control of steering, acceleration and braking, coupled with automatic warning and guidance systems, that are almost ready now for application to rural freeways. It would be interesting to know (a) how the costs of equipping both the vehicle and the highway can be justified in terms of safety or more efficient service, and (b) how these costs should be apportioned between private and public funds. These items, that affect future design and investment, are a natural concern of the highway engineer.

HIGHWAY DESIGN

Having examined the changes in vehicle designs during the past 30 yr, it is fitting to review the changes in highway design that have occurred during the same period. In their way they have been just as drastic as those in the vehicles.

Highway design is influenced basically by four factors, the volume, speed, size, land weight of traffic. Over the past 40 yr there has been a shift in emphasis from the static design aspects (cross-section, profile, sub-grade, and drainage), that were important in obtaining economical construction and life, to the dynamic aspects of geometric design needed for high operating speeds and smooth flow of traffic. Table 2 indicates design standards for two-lane primary rural highways for both 1927 and the present day. It reflects the shift from the static to the dynamic, but more importantly it reflects the changes in highway design which have been necessitated by changes in vehicle characteristics. It will be noted that design speeds have doubled and thus increased the requirements for pavement and roadway widths, bridge widths, and horizontal alignment.

The change in pavement design is well illustrated by Table 3, which lists pavement design trends from Delaware's road life files. The decade-by-decade growth in pavement widths and thickness is clearly evident. Computation of the pavement quantity required to provide a 25-ft slab 10 in. thick compared with

that to provide an 18-ft slab 7 in. thick shows that nearly twice as much pavement is required per linear foot. The contrast is even more marked by comparing Figs. 5 and 6. Fig. 5 shows a 16 ft secondary road with a concrete pavement constructed in 1926 (photo taken in 1934 after adding wearing course).

TABLE 2.—DESIGN STANDARDS TWO-LANE PRIMARY RURAL HIGHWAYS

Items (1)	1927 (2)	Current (3)
Design Speed, in miles per hour	35	70
Right of Way, in feet	80	100-120
Bridge Loads	H-15	H20-S16
Bridge Roadway, Width, in feet	24-30	44
Grades, in %	5-6	3-5
Horizontal Curve Radius, in feet	600	1500-1800
Roadway Width, in feet	32-40	44
Pavement Width, in feet	18-20	24
Sight Distance, in feet	500 (Passing)	600 (Stopping)
Eye Height, in feet	5.5	4.0 (Desirable)
Vertical Clearance, in feet	14	14

TABLE 3.—RIGID PAVEMENT DESIGN TRENDS TWO-LANE RURAL HIGHWAYS

Decade (1)	System (2)	Pavement Width, in feet (3)	Pavement Thickness, in inches (4)
1920's	Primary	18	7
	Secondary	16	7
1930's	Primary	20-22	8
	Secondary	16	7
1940's	Primary	22	8
	Secondary	18	7
1950's	Interstate	25[a]	10
	Primary	24	9
	Secondary	24	8

[a] One-Half Divided Highway.

Fig. 6 is a recent photograph of a major primary route, with six 12-ft running lanes, adequate median, and collector-distributor roads, each with two 12-ft lanes.

The need for adequate shoulder width to provide lateral clearance and emergency parking areas has been generally realized through the years. The serious

FIG. 5.—ADEQUATE SECONDARY ROAD OF THE 1920's

FIG. 6.—PRESENT DAY PRIMARY ROUTE

effect of inadequate shoulders in vehicle placement on the pavement has been demonstrated. Fig. 7 shows a comparison of what was considered adequate centerline clearance in 1927 with observed clearances on a high type, two-lane roadway in 1957. The example illustrated is for a condition of meeting opposing traffic. With narrower shoulders or without opposing traffic, vehicle placements were closer to the centerline.

Table 2 indicates that vertical alignments have changed considerably. Profiles must now be flatter to accommodate the lower eye-heights of modern vehicles and the longer stopping sight distances required by higher speeds. The illustration in Fig. 8 shows vertical curve requirements for various design conditions. It will be noted that the current requirement calls for considerably more excavation on a crest vertical curve than was necessary 30 yr ago. It has become almost impossible to provide passing sight distance on other than flat terrain, and the consequent limitation in passing opportunities effectively reduces the capacity of a two lane highway. Two lane roads with continous long grades have required the addition of separate climbing lanes to overcome the capacity loss occasioned by the operating speed differential between truck and cars. The need for maximum curvature limits of 3° to 4° resulting from design speeds 70 mph or higher also entails added costs per mile of highway. It is no longer easy to avoid expensive right-of-way situations or areas of excessive excavation or fill. Added expense is further incurred in intersection design to accommodate turning radii of long single units or trailer type vehicles.

The effect of being unable to keep highway design up-to-date with vehicle design is obvious from the following example. The Cross County Parkway north of New York City was adequately designed for the vehicle-operating characteristics of the times. Its operational characteristics today have not been affected by either right-of-way encroachments or the introduction of at grade intersections. Traffic volumes have, no doubt, increased beyond capacity and accident rates may be higher than those usually found on such highways. To combat these conditions, the heavy opposing flows have been separated by installation of a barrier median at the centerline of the four-lane, undivided pavement. With lane widths already less than those considered adequate today, the addition of a median barrier has the effect of reducing the width still further. At a speed level as low as 35 mph the feeling of restriction that is conveyed to the driver makes the trip a harrowing experience akin to being jostled in the subway at rush hour. This can solely be ascribed to lane widths inadequate for the present widths of passenger vehicles. Parallel routes are evidently needed because of excessive traffic volumes. But the present roadway, based on advanced design of the 1930's, will not accommodate the original design hour volumes because of the increased speeds and dimensions of passenger vehicles. Such situations lead to the question of the amount of land that must be provided for new highways to replace those made obsolete by increasing traffic or inadequate original design.

There are other aspects related to highway design which can be mentioned in passing. One previously alluded to is that of driveway problems. Changes in vehicle dimensions have made driveways constructed to old standards obsolete. The problem of dragging tail pipes of dented mufflers has been a common experience. The highway engineer, not the manufacturer, is on the receiving end of the resulting irate telephone calls. Another irritating operational problem is that of pushing disabled cars with varying bumper heights. A more expensive concern of the traffic engineer is the need for provision of

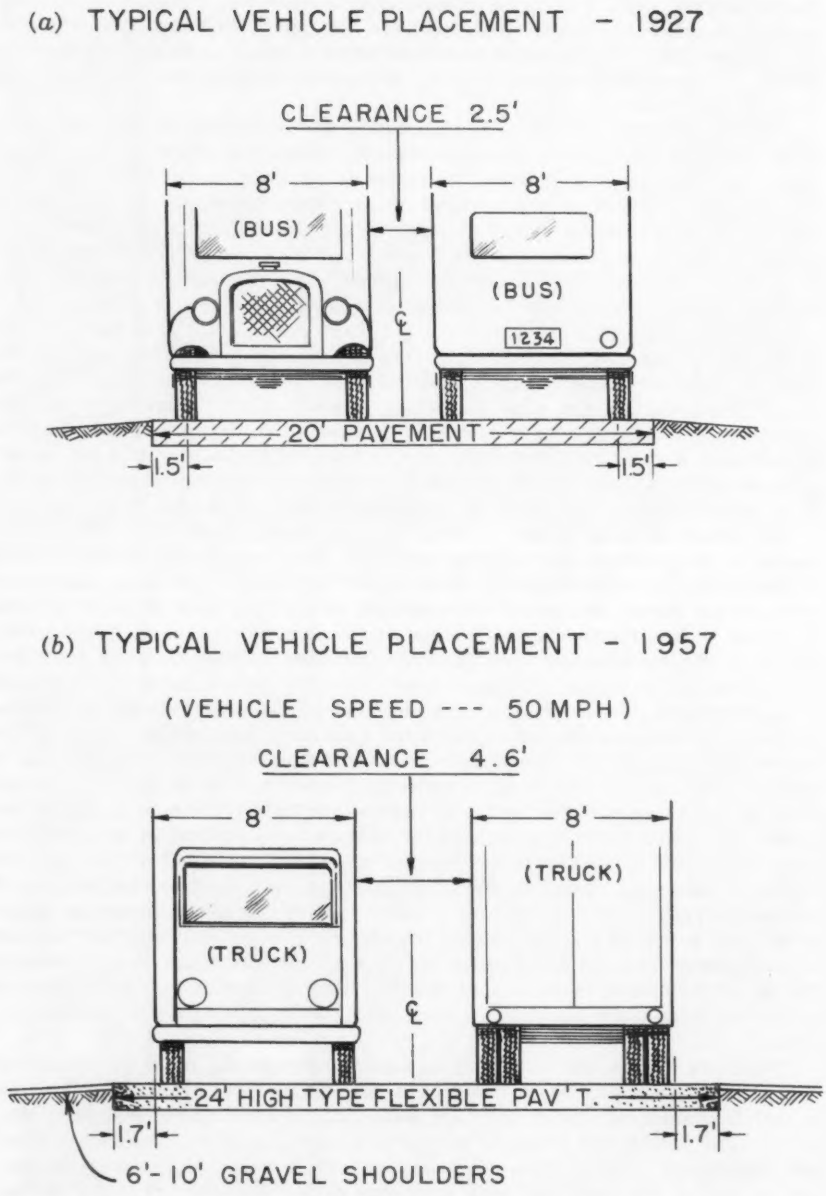
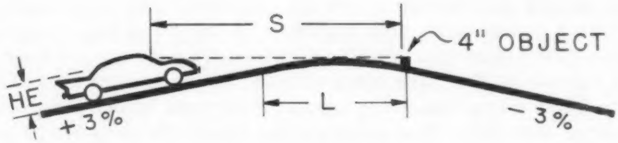
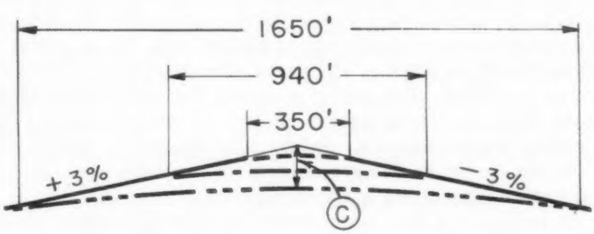


FIG. 7.—TYPICAL VEHICLE PLACEMENTS



DESIGN FACTORS	1927	1950	1960
ALGEBRAIC CHANGE OF GRADE	6 %	6 %	6 %
DESIGN SPEED (MPH)	35	60	70
HEIGHT OF EYE ABOVE ROAD (FT.) (HE)	5.5	4.5	3.95
SAFE STOPPING SIGHT DISTANCE (FT.) (S)	300*	475	600
LENGTH OF CURVE REQUIRED (FT.) (L)	350	940	1650

**approximate*



YEAR	C FT.	Δ FT.
1927	2.63	
		4.42
1950	7.05	
		5.35
1960	12.40	

1960 CREST GRADE IS 9.8' BELOW 1927 CREST GRADE.

FIG. 8.—VERTICAL CURVE DESIGN 1927 TO 1960

traffic signals over each lane on multi-lane facilities because vision is obscured by the heights and widths of trucks. Another item of concern to the highway or vehicle commission administrator is that of design modifications that make existing laws obsolete. Modifications, such as changes in head lights, tail lights, and vehicle widths have come about without apparent regard for existing statutes. Sales often rise to the tens of thousands before these conflicts are called to public attention. This situation has raised the question of how long must this sales directed disregard of vehicle codes be tolerated by public bodies.

A more costly area of concern is that of parking. Terminal facilities are becoming recongnized as an integral part of the highway problem. Brief mention will be made here of this subject.

The problem of the one car garage whose occupant outgrows the stable is well known. The problem is more costly with respect to commercial parking garages. The amount of parking space in such facilities depends largely on the column spacings and aisle widths of the original design. The increasing lengths, width, and turning radii of passenger vehicles have, in many cases, significantly reduced the capacity and revenue-earning ability of such facilities. The same is true of parking lots, although these can adjust more radily to the increased size of the passenger car. Even curb parking is affected by the increasing length of cars. The need to make parking spaces 22 ft long caused a 17% reduction in the number of spaces available, according to a recent survey in Pittsburgh.

A major question is - how much highway design is predicated on compensating for the lack of safety built into the vehicle and induced in the driver as a result of vehicle characteristics? It is felt that design considerations of median widths, median barriers, and guardrails are influenced by either or both of the above factors. In a recent report[4] these points are raised, (a) a better view of the right edge of pavement is needed, (b) more skid resistance between the pavement and the tire is needed. The report suggests that automobile design changes are the results of a continuing series of compromises between demands for styling and safety improvements. Safety improvements should improve the opportunity for the motorist to have control of the vehicle at all times and to react more effectively in times of an emergency.

Widening of pavements has been required to accomodate existing traffic more safely. There are times when it appears that the increased widths are used as justification by manufacturers and commercial groups to increase still further the size of their vehicles.

All of this adds up to a frustrating experience to the highway engineer. Highway design changes in the past have necessarily followed changes in vehicle design. But because the highway engineer is unaware of the manufacturers' longrange intentions, he has been building obsolesence into the highways at almost the same rate as the vehicle designer has been building obsolesence into the vehicle.

TODAY'S CRITICAL SITUATION

It is appropriate to review the present plight of highways and traffic operations resulting from the adjustments made to accommodate both vehicles and highways to the demands of society.

---

[4] The Federal Role in Highway Safety, House Document No. 93, Washington, D. C., 1959.

Whether the conditions existing on Delaware's highways are comparable to those of other states is difficult to say. But they are the conditions which have to be faced by at least one State Highway Department. Over the 512 miles of Delaware's primary highways, the system average of daily traffic exceeds 6500 vehicles. This traffic is carried on a network composed of 166 miles of 4 or 6 lane, divided highway, and at the other extreme, approximately 200 miles of two-lane highway, 22 ft or less in width. It is estimated from sufficiency studies that 247 miles need widening, exclusive of added lanes, a figure which includes mileage on divided highway lanes of 22 ft or less width. Despite the major emphasis in recent years on providing adequate pavement widths, it is obvious that construction has not yet caught up with the needs.

In terms of dollars, it is estimated that the cost of a two-lane primary rural route on new location is now $200,000 per mile. Taking into account deflation of the dollar, which is counter-balanced by improvements in construction productivity, this is a spectacular increase from the costs of $40,000 per mile for the same highway in the 1920's. Costs of major roadway items are listed in Table 4, which has been excerpted from a part of Delaware's response to the Section 210 Study. While some reductions in major cost items would result if design were based on 3000 lb axle loads, modern design, for passenger vehicles only, still results in costs far exceeding those of 30 years ago.

Truck weight studies in Delaware show that one-third of the commercial vehicles sampled in 1958 had gross weights of 45,000 lb or more. In 1941, there were no vehicles recorded with gross weights exceeding this figure. The average gross weight of all loaded vehicles in the 1958 survey was 46,000 lb, against a 1941 average of 32,000 lb. And the fact that applications for oversize or overweight vehicle movement permits have risen in Delaware approximately 600% in the past decade offers further evidence of the vehicle trends. In reply to a recent AASHO survey, 43 states noted an increasing number of permits for 10-ft wide house trailers, and 34 states remarked on the pressure existing to liberalize regulations. Of 14 states which permit movements of 12-ft wide trailers, 9 reported an increasing number of movements and pressure for an easing of restrictions.

The situation in current traffic operations poses some questions. The assortment of vehicles ranges in size from children's bicycles, through compact and "normal" cars, to 100 ft long, 65 ton freight vehicles. That there is at least segregation of the two extremes mentioned is something for which to be thankful. But the Delaware State Police recently investigated an accident on a high speed divided highway in which a tractor trailer had, without physical contact, turned over a small European car by the shock wave or back-wash while passing. The problems of being able to see the moving small car, the stopped school bus, or a changing traffic light when traveling behind, and preparing to overtake a tractor trailer are common experiences. The sight of columns of cars following a slow moving truck on an upgrade or even on flat terrain is not unusual. The possibility that exposed tandem wheels at the sides of trucks have an adverse psychological effect on small car drivers has been raised. None of these conditions are conducive to highway safety, and they give rise to public comment on the possibilities of separate roadways for 200,000 lb trucks and 1500 lb cars. It is a matter which merits study.

The cost of such investigations is small compared with the annual investments made by government units for highway purposes. Fig. 9 indicates the trend, in actual dollars spent, and in dollars adjusted to a 1957 base. In 1958 the total expenditures for all highway purposes, including maintenance and police, was

approximately 9.8 billion dollars. The costs of future highway programs will be considerably higher if the growth of vehicle registrations contines at the rates shown in Fig. 10 for the past 10 years. The cost of the interstate system estimated in compliance with the 1956 Federal Highway Act, is over 32 billion dollars. The estimated cost to provide the Washington metropolitan area with a transportation system adequate for 1980 is 2.5 billion dollars. Another example of future costs can be seen in California's approved plan for the construction of 12,000 miles of freeways -- equivalent approximately 1/3 the National Interstate Highway System.

These programs will not be entered into lightly. Maximum knowledge of future needs is mandatory for judicious design. But can the designer feel assured, as he designs for the vehicle of today or even for those of the immediate

TABLE 4.—VARIATIONS IN GEOMETRIC DESIGN STANDARDS AND COSTS FOR PRIMARY RURAL ROADS[a]

Items	Normal percentage of heavy vehicles		Light vehicles only Maximum axle load 3,000 pounds		% Difference	
(1)	2 Lane (2)	4 Lane (3)	2 Lane (4)	4 Lane (5)	2 Lane (6)	4 Lane (7)
Surface thickness	9 in.	9 in.	7 in.	7 in.	- 22	- 22
Surface width	24 ft	48 ft	22 ft	44 ft	- 8	- 9
Surface type	Concrete	Same	Same	Same	. . .	. . .
Shoulder width	10 ft	10 ft	8 ft	8 ft	- 20	- 20
Vertical clearance	14 ft	14 ft	10 ft	10 ft	- 29	- 29
Grading and drainage cost per mile	70,000	155,000	64,600	148,200	- 9	- 4
Shoulders cost per mile	1,700	6,900	1,300	5,500	- 24	- 20
Pavement and base cost per mile	89,000	178,000	69,500	139,000	- 22	- 22
Sub total	160,700	339,900	135,400	292,700	- 16	- 14
Interchange grading and drainage	105,000	120,000	. . .	92,000	. . .	- 23
Interchange shoulders	5,000	5,000	. . .	900	. . .	- 80

[a] Carrying light vehicles only and for roads carrying a normal percentage of heavy vehicles (flat terrain).

future, that his creation will not be rendered obsolete by some new, unheralded departure in vehicle design? On the basis of past performance, he cannot.

RESEARCH ACTIVITIES

The best measure of the concern of highway engineers regarding the problems of relating vehicle design to highway design is the amount of research activity which is currently underway. Within the Highway Research Board, the Department of Design, the Department of Economics, Finance and Administration, and

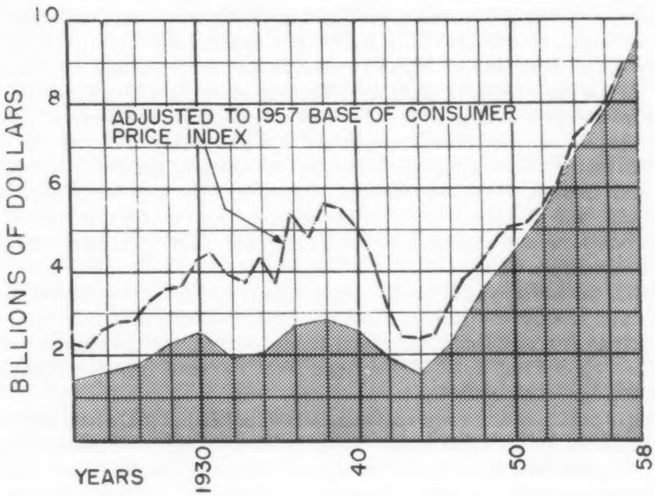


FIG. 9.—ANNUAL EXPENDITURES FOR HIGHWAY PORPOSES BY ALL UNITS OF GOVERNMENT SINCE 1922

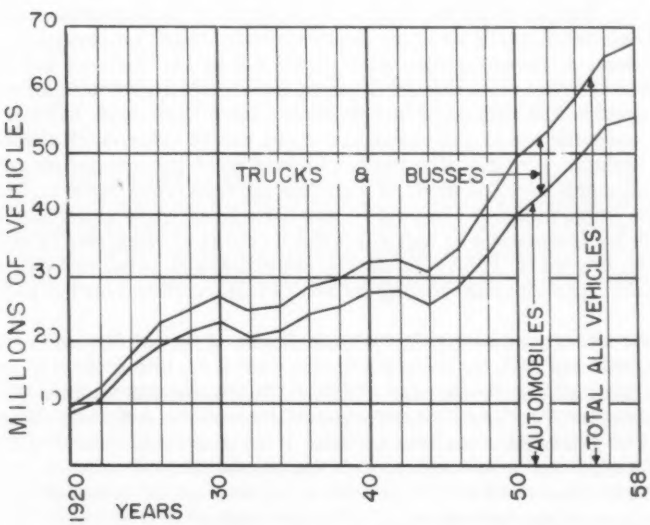


FIG. 10.—VEHICLE REGISTRATIONS 1920 TO 1958

the Department of Traffic and Operations are engaged, through various committee activities, in researching this problem. All told there are 20 committees of the Highway Research Board investigating areas in which the design of vehicles affects highway design. The American Society of Civil Engineers has a committee on geometrics of highway design and a committee on traffic engineering. In the American Society for Testing Materials a committee is being formed to investigate skid prevention. The American Association of State Highway Officials has at least five committees that are engaged in research related to this problem, the Operating Committees on Bridges and Structures, Design, Planning and Design Policies, Design, Construction, and Maintenance of Secondary Roads, and Traffic. The Technical Division of the Institute of Traffic Engineers has four departments whose activities must take into consideration the trends in vehicle design.

Generally, the activities of these committees represent the part-time efforts of highway and traffic engineers, most of whom are in public service. None of the committees are supplied with direct funds to engage in research. Research studies, when conducted, must be financed from Federal Highway Planning Survey funds and/or local budgets.

A listing of publicly or privately financed research projects has been obtained from the Highway Research Board. Twenty-seven subjects related directly or indirectly to problems of vehicle design and highway design can be tabulated. Many of these subjects are being studied by more than one agency. For example, under the heading of "Median Studies Related to Vehicle Accidents" studies are being conducted by the California Division of Highways, the New Jersey Turnpike Authority, and the New York Department of Public Works. Groups engaged in highway research include the automotive industry, various trade associations, the Bureau of Public Roads, State Highway Departments, and transportation research centers or other departments of many universities.

Other research investigations were instituted by the Federal Aid Highway Act of 1956. This act directed the Department of Commerce to undertake the so-called Section 210 Studies, which included investigation of (a) the effects on design, construction and maintenance of the use of vehicles of different dimensions, weights and specifications, (b) studies of the proportionate share of cost allocations, and (c) study of benefits derived from highway improvements. The Department of Commerce was also directed to undertake studies pertaining to improvements in highway safety. These studies have involved the efforts of the Bureau of Public Roads, the State Highway Departments, universities and other groups in developing the desired information over the past three years.

The major research activity, however, in terms of investment and scope has been the AASHO road test. In progress for the past 3 yr, this project is financed by the individual states, the Bureau of Public Roads, the Automobile Manufacturers Association Portland Cement Association and the American Petroleum Institute. The principal objective, reduced to its simplest form, is the determination of significant relationships between pavement performance and loads applied. Other objectives aim at providing related useful information to the highway designer and administrator. The total cost of this single study is estimated at approximately $22,000,000.00. Administration and direction for the project is being provided by the Highway Research Board of the National Academy of Sciences - National Research Council.

According to information supplied by the American Association of State Highway Officials, the amount spent in 1958 on all highway research activities, of

which those described have been a part, was slightly under $18,000,000. The 1958 expenditure for all highway purposes by all units of government was slightly under $10,000,000,000. The research effort therefore is less than 2/10 of 1% of the total highway expenditures. Comparison of these figures with the research and development expenditures for private industry points up a noteworthy contrast. In the chemical industry, as a whole, it was estimated that in 1958 $600,000,000.00 or 3 to 4% of sales were spent on research. The 1958 annual report of E. I. DuPont de Nemours and Company, Inc., which is notably research minded, showed expenditures on research and development of $90,000,000 or 4.9% of gross sales.

The comparison is by no means justification for saying that highway research expenditures should be increased to the level of those of private industry. However, the significant difference which appears is, to say the least, disturbing. It is particularly disturbing when considering that the highway research effort outlined previously has been splintered among many diverse areas, and that the bulk of activities are committee operations involving the spare time activity of busy men in conferences, conventions, and reports for trade publications. It is fortunate that the efforts of these individuals have not been outstripped totally by the progress in vehicle improvements.

Is it enough to hope that the present nature of research activities can successfully meet the problems arising from vehicle design changes? Or will the following prophecy still apply?

> "There must be an arbitrary limit of load for which we can design our roads. Otherwise as fast as they are built, roads will attract to themselves traffic heavier than they are designed to bear. The road and the load will be forever outstripping each other with great economic loss both of original investment in the road and in the appalling high maintenance."

This warning was written in 1919 by H. E. Breed[5], then Deputy Commissioner of Highways for New York State. A more recent warning note was sounded by Robert Moses:[6]

> "The auto industry must play an increasingly important part. The period is over when the manufacturer loses interest when his car, truck or bus leaves the assembly line and the sales room . . . There must be freer exchange of information, more discussion of difficulties, more inspections of successful installations and above all, better leadership."

CONCLUSIONS

The present reappraisal of the highway program being undertaken by Congress and other official bodies is occasioned by charges of poor coordination between engineers and planners, of unsound cost estimates, and of extravagant design. Yet one congressman recently stated that the prime example of overdesign on the American highway system is the automobile itself. The real question is: Can the highway engineers and the highways they design remain isolated from the many manufacturers and the private and public organizations which are dependent upon the highway systems for their very existence?

---

[5] H. E. Breed Public Roads, January, 1919.

[6] Working for the People, by Robert Moses, Harper and Bros., New York, 1956.

The operation of a transportation system of the size and scope that exists today demands the best talent and the best thinking available. Even those who may feel that this is being provided must admit that research efforts are fragmented in terms of space, time, money, and manpower. We cannot afford to have our present and future investment in the National Interstate and Defense Highway System and other networks sacrificed through a lack of coordinated thought. Yet, common sense and engineering judgement dictate that a certain percentage of highway obsolescence must be accepted to achieve transportation progress. Common sense and engineering judgement, in the short term view, suggest also that the automotive industry and road user groups should defer major vehicle modifications until the findings of the 1956 Highway Act Studies and the AASHO Road Test can be made public.

An altogether too obvious solution to the problems which have been discussed is the establishment of further governmental bureaucracy to install controls, attempting thereby to protect the taxpayers' investment. Yet the very nature of such an agency would tend to hamper long range progress by restricting the competitive nature and creative thinking of a major industry and our own highway profession.

It is believed that an acceptable alternative is an expanded research program supported jointly by industry and all other interested agencies. This suggested new research effort will require a full time task force of workers in social and physical science disciplines as well as engineers from industry and public service. Equal emphasis must be given to the problems of manufacturers, users, and highway engineers.

In connection with the problem of correlating vehicle and highway design, certain functions should be assigned to such a research group:

1. Development of controlling maximum standards for vehicle design;
2. Determination of the maximum desirable life for any given set of standards;
3. Development of review procedures to permit periodic revision of standards;
4. Research to seek out new directions in highway transportation;
5. Determination of warrants for the installment of new system;
6. Dissemination of information to manufacturers, users, highway management, the public, and legislative bodies.

The precedent for such an organization has already been set. It is the AASHO Road Test, financed and directed by the major interested agencies and associations, public and private alike. The lessons in cooperation which have been learned as a result of this project can well be applied to the total problem at hand.

It is hoped that this paper will not be considered as merely self-indulgent tilting at the serenely rotating windmills of the automotive industry. This industry has a future no more sound than the foundations on which it is built. An integral part of the foundations is the national highway network. Like most foundations, highways are expensive, they must be conceived with a knowledge of the use to be made of them, and they call for optimum design to provide safe, efficient and economical service. Much more needs to be done by all concerned to achieve these ends.

ADDITIONAL REFERENCES

1. "Relation between Vehicle Characteristics and Highway Design," by K. A. Stonex, O. K. Normann, W. A. McConnell, L. H. Nagler, W. R. B. Froehlich, Highway Research Bd. Bulletin 195, Washington, D. C., 1958.

2. "Review of Vehicle Dimensions and Performance Characteristics," by K. A. Stonex, presented at the 39th Annual Meeting of the Highway Research Bd. 1960.

3. "American Driving Habits," by Ernest H. Doubleday, The Autocar, November, 1959.

4. "Principles of American Highway Design," by Dewitt C. Greer, Transactions, Vol. CT, 1953.

5. "Handbook for Highway Engineers," by Wilson G. Harger, and Edmund A. Bonney, McGraw-Hill Book Co., New York, 1927.

6. "Driver Behavior as Related to Shoulder Type and Width on Two Lane Highways," by Asriel Taragin, Highway Research Bd. Bulletin 170, Washington, D. C. 1958.

7. "The Highway Cost Allocation Study," by G. P. St. Clair, Proceedings, ASCE, Vol. 85, No. HW1, January, 1959.

8. "AASHO Road Test Project," AASHO Highway Transport Committee, 1955.

9. "The Truck Weight Problem in Highway Transportation," Highway Research Bd. Bulletin 26, Washington, D. C., 1950.

Journal of the

HIGHWAY DIVISION

Proceedings of the American Society of Civil Engineers

CONTENTS

DISCUSSION

TESTS OF CONCRETE PAVEMENTS ON GRAVEL SUBBASES[a]

Closure by L. D. Childs and J. W. Kapernick

L. D. CHILDS[1] and J. W. KAPERNICK.[2]—The writers agree with Mr. Friberg that pavement slabs do not meet the dimension requirements necessary for the assumptions of present pavement stress formulas. However, subgrade pressures fall off rapidly with distance from applied loads so that the difference between predicted behavior of an infinite slab and measured behavior of an actual pavement slab is tolerable. The discrepancies between theory and experiment are likely to be of the same order as the variations induced by nonuniformity of subbase materials, compactive effort, and moisture content. Mr. Friberg's sector analysis method is subject to the same dimension criticism as Westergaard's and Pickett's methods.

One apparent advantage of sector analysis is the choice of subgrade reaction relation. Friberg is not limited to the condition that reactive pressure is directly proportional to deflection. Also, arbitrary adjustments can be made in the successive approximation procedure to obtain realistic results for comparison with experiment when boundaries must be considered.

A disadvantage of Mr. Friberg's method is the fact that some engineering judgment is needed to carry the results to completion. Often the engineer would prefer to assign stress computation work to assistants. A simple designation of the physical constants and the proper formula are all that are needed in the cases of Westergaard and Pickett. Perhaps Mr. Friberg will develop a foolproof step sequence simple enough to be followed by untrained personnel in the near future.

The writers wish to thank Mr. Friberg for his remarks and suggestions. It is the writers' intent to include sector analysis in future papers as one of the standards for comparison.

[a] October, 1958, by L. D. Childs and J. W. Kapernick.

[1] Senior Development Engr., Transp. Development Sect., Portland Cement Assn., Chicago, Ill.

[2] Field Engr. Miller-Warden Assoc. Chicago, Ill.

PAVEMENT DESIGN PRACTICES IN VIRGINIA[a]

Discussion by George W. Ring

GEORGE W. RING,[1] A. M. ASCE.—Mr. Ellison's interesting paper describes the factors used to determine pavement design in Virginia. One factor, the soil "bearing value," is determined by a modified California bearing ratio (CBR) procedure in which a standard compactive effort of 45 blows per layer with a 5.5-lb hammer is used to prepare the test specimen. It is not clear, in Mr. Ellison's paper, whether the desired compacted density is 95% or 100% of maximum dry density as determined by American Assn. of State Highway Officials (AASHO) T 99-57 (Method A). He states:

> "Since our construction specifications require fills and subgrades to be compacted to a minimum of 95 percent of theoretical density as determined by AASHO Designation T99 standard Proctor density was selected for the test."

The purpose of this discussion is to show (1) that the density achieved by the Virginia method of compacting CBR specimens is about 100% of maximum dry density and (2) the CBR values at this density vary considerably from the CBR values at 95%, the compaction percentage normally specified for subgrades.

Test results obtained in conjunction with studies in the soils laboratory of the United States Bureau of Public Roads (BPR), indicate that CBR specimens compacted with 45 blows per layer give essentially 100% of the maximum dry density as determined by AASHO T 99-57 (Method A). The BPR test specimens were compacted by a method differing slightly from the Virginia method, but the two procedures give about the same compacted densities. The BPR test specimens were compacted in 4 layers into a mold 6 in. in diameter and 5 in. in height, giving an average layer thickness of 1.25 in. CBR specimens prepared by the Virginia method are normally compacted in 5 layers into a 6-in. diam by 6-in. high mold, giving an average layer thickness of 1.20 in.

In order to determine the effect of this difference in procedure, two compaction tests by each method were made on a micaceous silty clay, A-7-6 (13), using forty-five blows per layer.

The limited data in Table 1 indicate that the Virginia method may give densities slightly higher than the Bureau method. This should be expected since the same compactive effort is applied to a thinner layer in the Virginia method.

Tests were made on 7 soils samples to determine the effect of the number of blows per layer. The BPR compaction procedure was used. Fig. 1 shows the compacted density versus the number of blows per layer. At the vertical

---

[a] September, 1959, by K. E. Ellison.

[1] Highway Research Engr., Div. of Physical Research, Bur. of Pub. Rds., Washington 25, D. C.

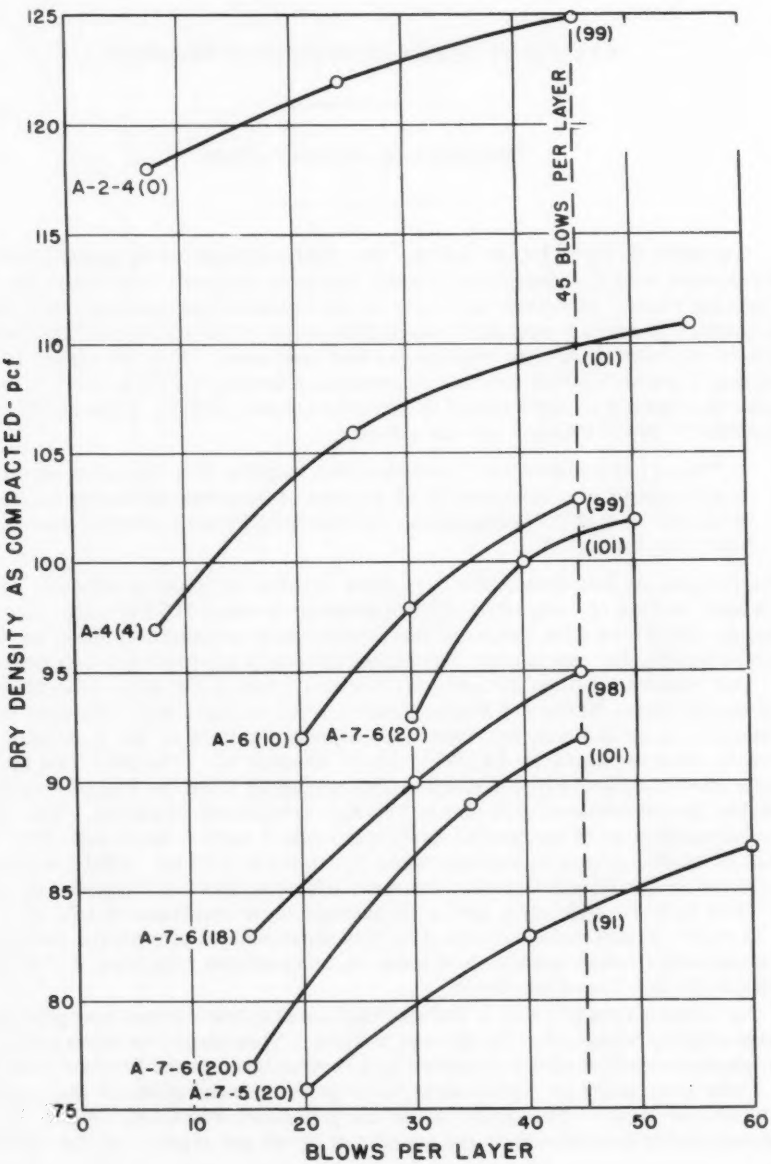


FIG. 1.—EFFECT OF NUMBER OF BLOWS PER LAYER ON COMPACTED DRY DENSITY

line for 45 blows per layer, the number in parenthesis near each curve is the percentage of the maximum dry density determined by AASHO T 99-57 (Method A). Note that the value for 6 of the 7 soils samples is close to 100%. The highly plastic clay reached only 91% compaction.

The effect of density upon the soil "bearing value" and the flexible pavement design thickness is shown in Table 2.

TABLE 1.—COMPARISON OF DENSITIES FROM VARYING COMPACTION PROCEDURES.

	Virginia method in pounds per cubic foot	Bureau of Public Roads method in pounds per cubic foot
Test 1	104.3	102.6
Test 2	104.4	104.3
Average	104.35	103.45

TABLE 2.—DATA FOR COMPACTED SOILS

AASHO classification	CBR value		Flexible pavement design thickness[a]	
	95 percent compaction	100 percent compaction	95 percent compaction	100 percent compaction
	Percent	Percent	Inches	Inches
A-2-4(0)	10	16.5	13	10
A-4(4)	6	15	17	11
A-6(10)	4	10.5	21	13
A-7-6(20)	8	11.5	15	12.5
A-7-6(18)	4	5.5	21	18
A-7-6(20)	4	6	21	17
A-7-5(20)	3	3.5	25	23

[a] For traffic category III

The Virginia design chart with a traffic category of III was used to determine the pavement thicknesses for the CBR values. The A-4 and A-6 soils show the greatest difference in design thickness for the two density conditions.

It appears that the Virginia method of compacting CBR specimens produces a greater density than is required during construction of the subgrade. Also, the CBR values for soils compacted to 100% of maximum dry density are significantly higher than the CBR values for the same soils compacted to 95% of the maximum dry density.

PASSENGER DATA FOR URBAN TRANSPORTATION PLANNING[a]

Discussions by N. C. Raab, Burton H. Sexton, William R. McConochie, John C. Kohl, Harold M. Lewis, and William H. Claire

---

N. C. RAAB.[1]—Mr. Cherniack's timely paper on urban transportation planning indicates the trend in mass transportation in and around the City of New York. An almost parallel example of this has been experienced in the San Francisco Bay area.

Although located some 3,000 miles apart, the cities of San Francisco and New York are geographically situated somewhat alike. They are partially surrounded by water, with the main business centers located so that the need for public mass transportation is essential for those who derive their livelihood in the densely populated downtown areas.

Transportation to these centers started first with the ferries, followed by rail, automobile, bus, and, to a limited extent, by air. Fig. 1 shows the passenger crossings of San Francisco Bay, and when compared with those for New York, there is a striking resemblance in so far as the rise and decline of the various means of mass transit are concerned.

In each case, the ferries, in the earlier years of the cities' growth, appeared to suffice the needs of those entering the highly populated areas. This convenience was augmented by rail transit, both steam and electric, that operated either directly into the cities or supported the ferry's shuttle system. After the advent of the automobile and its ever-increasing popularity for both business and private use, both ferry and rail traffic decreased, despite the increase in the communities' populations.

Along with the automobile, there came a period of conversion from rail to bus transportation, with the latter following the population increase, but at a much slower rate. There were several possible reasons for this trend. The bus lines, in most cases, were more economical to operate. They could be routed so as to serve the many communities in the outlying districts and deposit their passengers closer to their places of business.

However, before the automobile or bus could make any in-roads into supplanting ferry or rail transportation, bridges and tunnels were needed to cross the water gap isolating these cities from the surrounding communities.

In both cities, the rubber-tired vehicles probably would have taken over the public transportation of the masses if these vehicles could have been rapidly and economically taken off the city streets after their trips were completed. Off-street parking facilities and adequate bus terminals did not keep pace with the growth in population or popularity of this means of transportation. As a consequence, the congestion on the city streets became intolerable.

---

[a] December, 1959, by Nathan Cherniack.

[1] Proj. Engr., Calif. Dept. of Pub. Wks., Div. of San Francisco Bay Toll Crossings, San Francisco, Calif.

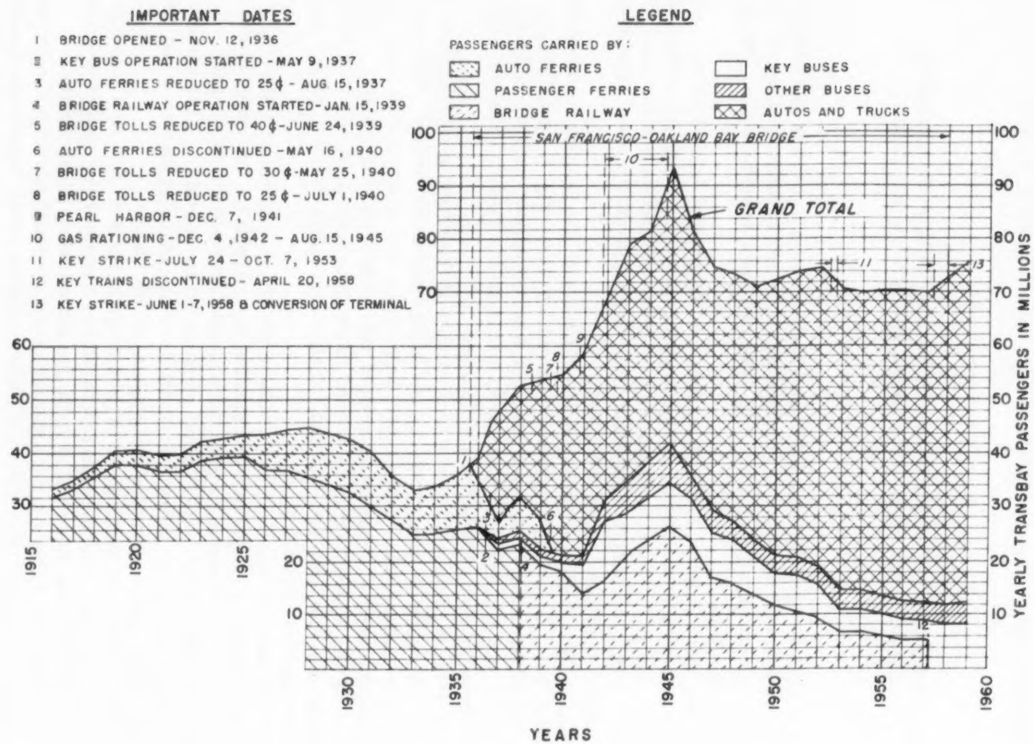


FIG. 1.—PASSENGER CROSSINGS OF SAN FRANCISCO BAY

Realizing this, the Port of New York Authority remedied the situation somewhat by the construction of the Port Authority Bus Terminal, into which the majority of the commuter buses entered by means of elevated ramps without using the streets in the immediate vicinity of the building. This plan is now being followed in San Francisco.

The San Francisco-Oakland Bay Bridge was opened to vehicular traffic on November 12, 1936, and from that time to the present there has been an ever increasing number of motor vehicles crossing the structure. The daily average in 1937, was 24,700 vehicles, and today it is over 100,000. On May 9, 1937, the first bus lines were started, and they were followed by interurban electric trains.

When the bridge railway was opened to the public (January 15, 1939) these facilities were used by the Interurban Electric, the Sacramento Northern, and the Key System. Although good, economical transportation service was offered the public, the first two companies had to abandon their lines over the bridge within the following two years, due to lack of patronage. The Key System converted a portion of its passenger transportation operation to motor coaches, paralleling, in some cases, the service provided by the trans-bay electric trains. This change was primarily brought about by economy in operation.

Patronage on the train service operated by this company steadily declined after World War II and in 1955, the Key System petitioned the Public Utilities Commission for permission to abandon service on its trans-bay rail lines and into the East Bay communities and inaugurate motor coach service to supplant their abandoned rail lines. The commission ordered this change, and on April 20, 1958, mass transit by motor coaches across the Bay Bridge became effective, supplanting the trans-bay rail lines.

The redevelopment of the transportation system for trans-bay commuter traffic was immediately started by the State of California under its Dept. of Public Works, and consisted of removing the tracks from the lower deck of the Bridge, paving over this area, and converting the structure, as well as its approaches, to vehicular use. Also, the Transbay Transit Terminal in San Francisco was converted from train to bus operation.

The terminal is a four-level building, having a garage in the basement, waiting and concession areas on the first floor, ticket offices on the mezzanine, and bus facilities on the 700 ft by 164 ft upper level. This level bridges over two city streets and all bus travel from the bridge to the terminal is by viaduct.

There were formerly six tracks running through the terminal in pairs of two and separated by columns supporting the roof. Trains were loaded from platforms on either side.

For bus operation, the columns were moved to the curb of the "off-side" platform. Rails were removed and the area paved, giving a two-lane roadway width of 25 ft.

Buses move longitudinally through the building and coach stops are located two bus lengths apart, providing 30 stations, 10 in each roadway. At each station a traffic treadle is located next to the curb. The right front wheel of the coach, on arriving, stops on the treadle, and the driver is notified as to his position by a telltale light on the left curb. At the same time, the letter indicating the arriving bus is lighted on the large indicator board on the first floor, and lobby of the building. Passengers then take the escalators or steps to the mezzanine, where smaller indicator signs direct the passenger to the proper ramp or steps leading to the loading platform. Directly over the bus, there

are two lighted signs giving the letter of the bus. In a total blackout, the indicator system is switched to a direct current line, furnishing sufficient illumination to guide passengers to the proper buses.

There are, at present (1960), two lines using the terminal facilities, operating 690 coach-runs in, and the same number out, each week day, with about one-half this number on Saturdays, Sundays, and holidays. They transport approximately 14,500 passengers each way.

Since the abandonment of train operation, bus traffic has increased on an average of 3% over the same months of the previous year. However, it is realized that despite this increase, other means of transportation will have to be provided to care for the public's needs. Plans are now being prepared for a five county rapid transit system covering the San Francisco Bay area. Bonds for financing the construction are to be voted on at a coming election. This system, as planned, will connect the municipalities on each side of the Bay by a tube, and then by subways through San Francisco and Oakland and by surface trains to the outlying areas.

It is quite apparent that the private automobile is not a solution to the problem, and it is highly improbable that bus lines will be able to continue to maintain efficient service using the present freeways, highways, and streets, due to congestion. It is possible that the cycle may return in part to the former means of mass transit, either above or below the surface, with the various lines using their own rights of way.

BURTON H. SEXTON,[2] M. ASCE.—The matter of the relative efficiency of franchise bus operations as opposed to rapid-rail transit has long been the topic of invalid reasoning. The proponents of rail transit have assumed that this form of commuter travel is the most efficient in terms of carrying ability, speed, and convenience. Mr. Cherniack's discussion of this factor places expressway bus operations within their proper perspective. To adequately illustrate the import of Mr. Cherniack's remarks, the writer would like to evaluate his paper in terms that are reflective of the Washington, D. C. Transportation Plan,[3] hereinafter described as the plan. It will also be helpful to extract comments from a report, "Traffic and Transportation Aspects, Transportation Plan, National Capitol Region,"[4] hereinafter described as the report.

As the Cherniack paper states, rapid-rail transit has for years been rated at an operating passenger capacity of 40,000 persons per hr. The rapid-rail operating capacity is generally compared to a bus operating capacity of only 3,000 persons per hr. The point of improper evaluation is this simple. The rail figures are based upon a rapid transit operation upon private rights-of-way while the bus figures are based upon a local city bus operation. Actually, an express bus system operating over an expressway can achieve an operating capacity in excess of 25,000 persons per hr. In many cases costly rapid-rail operations have been supported on passenger carrying ability with insufficient thought given to the flexible expressway bus operation.

---

[2] Senior Partner, Sexton-Sexton and Assoc., Professional Engrg. Consultants, Traffic-Noise-Transportation, Washington, D. C.

[3] "Transportation Plan for the National Capital Region," Natl. Capital Planning Comm. and Natl. Capitol Regional Planning Council, Washington, D. C., 1959.

[4] Prepared by Burton H. Sexton for A. B. and W. Transit Co. and W. V. and M. Coach Co. Presented by Manuel J. Davis at Hearings Before the Joint Committee Washington Met. Problems, Congress of the U. S., 86th Congress, 1st Session, November, 1959.

The description of a typical New Jersey suburban bus operation is similar to that system of expressway bus operations that were recommended in the report.[4] Namely, the expressway bus operation would collect passengers in satellite communities and perform an expressway trip to downtown Washington or other employment centers, thereby eliminating the chief time loss factor attributable to rapid rail transit or feeder bus operations, the multiple transfer. It adds to an efficient transit operation, which cannot be achieved by fixed rail, the most important factor of flexibility.

It is obvious that a highway or expressway lane, whether designated as an exclusive transit lane or not, more efficiently serves public travel since it is in continuous use 24-hrs a day, each day of the year. As the author points out, a similar fixed-rail facility is chiefly in use only on the track of the dominant flow direction during the rush hour periods. Hence, the maximum use on the inbound and outbound tracks is only 3 hrs during the appropriate morning and evening rush hours. Based upon this hourly rate and upon 250 weekdays per year, each track achieves a maximum use of only 750 hrs per year. This "gargantuan," fixed cost facility produces a maximum use of only 9% of the available directional hours annually.

The plan[3] purposes, in addition to an expressway bus system, coupled with a feeder bus operation, a fixed rail system of four main lines and a downtown subway. The justification for rail service is based upon serving high density employment and residential areas. However, as the report points out:

1) The expanded number of 1980 trips that is anticipated from a 50% increase in regional population cannot support a tripling of the highway and transportation system.

2) If the employment within the District of Columbia increases less than it does in Prince Georges County and within Fairfax County and Falls Church and equals the employment increases in Montgomery County, how can the plan[3] support the need for a $500,000,000 rail system with 80% of the construction cost within the District of Columbia?

3) The majority of the added population and employment will occur outside of the District of Columbia. (80% outside population while employment increases only 11% within the District of Columbia). Rail service is intended to serve high density areas banked against the main rail lines and cannot attract sufficient numbers of persons otherwise. The above added to the inconvenience of a multiple transfer, that will be necessary under the rail plan, will not attract sufficient transit patrons to warrant a rail system.

4) The most important single item within the plan that was not significantly brought forth, was the relocation of suburban employment centers and the resulting shifts in complementary population and the obvious result of increasing intra-area trips and not inter-area trips to and from the central business district. In fact, practically all of the planning has been based upon inter-area trips with little or no emphasis upon intra or circumferential trips. This, it is believed, has led to an erroneous conclusion.

5) The sole proposal for assisting the intra-area trips as stated in the plan was as follows:

> "The only logical solution to the transportation problem of the new Metropolitan Area is to provide a new form of transportation so attractive that many rush hour travelers to downtown will use it and thus leave space on the highways for those who must use their automobiles for these new non-downtown trips."

6) An expressway bus plan offers a flexible transit plan and one that can be efficiently operated by private enterprise.

7) The expressway bus plan that is foreseen[4] includes, in part, the type of operation discussed in the plan, in that some of the buses will not leave the expressway until they arrive within the central business district. However, to eliminate a feeder operation, the express buses will traverse the residential and industrial communities and then enter the expressway system for an uninterrupted trip to the central business district.

8) The expressway buses will operate upon the highway facility. They will mix with other traffic or travel upon special bus lanes until the facility approaches capacity at which time the median will be converted to an express-bus roadway or a reversible roadway for all traffic. The existing transit service will, for the most part, remain and will provide the commuting service between the expressway and street system without imposing additional transfers from bus to bus.

9) Such expressway bus service is presently in operation within the Washington, D. C. area on a small scale. Proper expressway facilities and cooperation from the various federal and state highway and traffic agencies can produce a highly effective expressway bus system.

The expressway bus system would utilize existing or proposed expressway facilities without the burden of an elaborate publicly owned fixed-rail system, that totals in excess of a half a billion dollars and is based upon deficit financing. Mr. Cherniack's comments are definitely in agreement with the report:

> "Today, capital investments in new systems of rail transit facilities do not appear justified. Studies have invariably pointed to substantial deficits because such new proposed systems of rail mass transit would only satisfy largely only the weekday journey-to-work demand to and from the C.B.D. The weekday non-C.B.D. travel, 'reverse travel', and expanding week-end leisure time travel demand would still have to be met by limited access highways. These limited access highways could also satisfy the journey-to-work demand with express buses and preferential or exclusive bus lanes, if required."

The writer has attempted, through the preceding comparisons, to point up the need for flexible urban transportation planning. The planning for urban transportation is a dynamic process and one which should not be chained to a fixed rail mode of travel. The urban transportation demands can be met under the Interstate and Defense Highway System, with expanded consideration within urban areas.

The modern expressway has produced a "road-bed" for buses to provide service with speed and operating capacity that is competitive with fixed-rail service. It is more convenient in that it improves linkage, thereby reducing transfers. Most important, it is flexible and can keep abreast of changing urban demands. Lastly, it is more economical and withdraws the threat of publicly owned transit operations. The planning of expressways now under consideration in urban areas should include immediate design features and priorities, if necessary, for expressway bus operation, that would provide rights-of-way sufficient for exclusive bus lanes and medians that can be utilized for bus roadways or reversible lanes for all traffic.

WILLIAM R. McCONOCHIE,[5] M. ASCE.—Mr. Cherniack has produced an excellently documented treatise on transportation, with particular attention to the problem of commuter transportation across the Hudson River in the New York and New Jersey Metropolitan Area. The author has made a major contribution toward the solution of a perplexing problem which affects not only this area, but all other large metropolitan areas.

The writer is in agreement with Mr. Cherniack on essentially all of his conclusions. However, it is believed that the author has over-stated the current situation in saying "Today, capital investments in new systems of mass rail facilities, do not appear to be justified." Investments in new rail systems are currently being made—wisely—in Toronto, Chicago, and Boston, and are currently under serious consideration in such cities as Washington, D. C., San Francisco, Philadelphia, and elsewhere on this Continent, as well as in several foreign countries.

The key to any possible disagreement on this matter is in the statement that rail rapid transit has a rated passenger capacity of 40,000 persons per hr on a single track whereas buses can carry between 20,000 and 25,000 passengers per hr in a single lane of an expressway. The latter figure is based on the operation of buses through the Lincoln Tunnel at New York, with which Mr. Cherniack is intimately acquainted. It must be remembered, however, that the buses flowing through Lincoln Tunnel do so without any station stops enroute and that very few stop after entering the approach expressways. Were all buses to stop at any one wayside stop in the Tunnel, or on the final approach, the capacity would drop to something on the order of 6,000 passengers per hr or speeds would fall to unacceptably low levels. It is also important to note that the impact of 450 to 500 buses per hr arriving at the Manhattan end of the Lincoln Tunnel requires an enormous terminal having 112 loading berths of which 40 are used for long-haul buses and 72 for commuter buses.

Congress Street Superhighway in Chicago is a case in point. The rail rapid transit facility in the center mall carries over 11,000 passengers in the heaviest hour on a single track while the adjacent four-lane roadway carries about 7,500 people. Patronage of the rail line has increased about 30% in less than two years, but the highway is carrying fewer people in the rush hour than it did in the initial weeks of operation. The highway is loaded essentially to its capacity, although it does not reach directly the heavily populated suburban area it will eventually serve.

The 11,000 people now using rail rapid transit in the peak hour could not be transported in buses in the general traffic stream without seriously disrupting operation of the expressway. The transit service would also be much less regular, probably slower and otherwise less attractive. Finally, the 200 buses per hr in the rush direction which would be required would congest Loop streets or necessitate a large terminal from which passengers would have to walk or transfer to other public transportation.

A full discussion of this subject is presented elsewhere.[6]

JOHN C. KOHL,[7] M. ASCE.—Mr. Cherniack has made a significant contribution to urban transportation planning because, unlike so many writers on

---

[5] Chf. Engr., Traffic and Transit Dept., DeLeuw, Cather and Co., Chicago, Ill.
[6] Proceedings of the Institute of Traffic Engineers, September, 1959.
[7] Director, Transp. Inst., Univ. of Michigan, Ann Arbor, Mich.

this subject, he has drawn his conclusions only after careful analysis of factual data. Further, he has importantly emphasized the limited, if not declining, role of existing mass transit on rails, and outlined the need for carefully planned locations of mass activities if the possible advantages of such transit are to be realized.

There is nothing inherently sinister in the automobile despite the deprecations of the "anti-auto-school" of planners now so active in delineating metropolitan rapid transit systems that would require continuing public subsidy. A conscious effort to verify and expand Mr. Cherniack's conclusions should produce really effective plans for urban transportation, and achieve the popular acceptance of such plans. That acceptance is certainly lacking for the proposals now current.

HAROLD M. LEWIS,[8] F. ASCE.—Mr. Cherniack's paper has given a very interesting and complete analysis of trans-Hudson River passenger movement between the Borough of Manhattan, in New York City, and New Jersey. This is supplemented by a more general presentation of trends, since 1911, emphasizing the shift, since 1930, from rail facilities to travel by motor vehicles. The author has analyzed the trends in the 1948-58 decade and, based on these trends, he has reached some rather general conclusions as to the suitability of various methods of passenger movement to meet future needs. The author implies that mass transit on rails will continue to give way to travel by private automobile and motor bus as he expects the present trends to continue.

Ten years is a very short time in the history of passenger transportation in the New York-New Jersey Metropolitan area. The writer believes that any predictions as to future trans-Hudson movement between New York City and New Jersey would benefit by delving further into history and examining some of the conclusions and predictions reached by earlier studies, and seeing to what extent these have proved valid.

One of the first comprehensive surveys[9] of trends in such movements was made by the Regional Plan Association under the writer's direction in 1935. It analyzed trends of the New Jersey railroads (1911-1934) and trans-Hudson movement of all kinds for the decade 1924-1934. Some of the conclusions reached in this report are compared below with developments since that time.

(a) It was concluded that "The low point in the decline of passenger traffic between New Jersey and Manhattan has been passed and considerable increases may be expected during the next few years." This was based on the same figures as are shown in that portion of Fig. 1 in the author's paper up to the year 1934, at which date the downward trend, resulting from the depression of 1929, showed the first signs of recovery. The Regional Plan prophesy was borne out, as the general trend for total movement continued upward (with a few small temporary setbacks) until 1955. Over the three following years the total curve dropped slightly. This may be only a temporary drop due to the overcrowding of existing facilities and the writer believes that, on completion of improvements under way on the George Washington Bridge, the upward trend will be renewed.

(b) A portion of the diversion from private automobile to mass transit in the 1930's was thought to be "permanent" but it was felt that "part of it has re-

---

[8] Cons. Engr. and City Planner, New York, N. Y.

[9] "Survey Throws Light on Need for New Facilities Across the Hudson River," Information Bulletin No. 25, Regional Plann Assn., Inc., June 17, 1935.

sulted from a combination of such temporary conditions as part-time employment and greatly decreased income." Mr. Cherniack's analysis shows that the diversion has not proved temporary but has steadily increased in the long-time picture, with a temporary hump in railroad commuter and bus traffic during World War II as a result of gasoline shortages and the resulting rationing.

(c) It was stated that "With the increased interest in active recreation, greater convenience and decrease in travel time between home and place of work will become more important to the commuter." This has proved true and the writer believes it is an important factor of the problem today when the commuter is still seeking relief. If he cannot get it, he will be forced to find another way of life in which his daily trip to work is more convenient and shorter in travel time.

(d) Also, "Motor vehicles cannot supplant rail facilities as a means of commuter transportation between New Jersey and Manhattan." While this still seems a sound conclusion, the railroad companies appear willing to throw in the sponge and Mr. Cherniack concedes only that "rail transport is still the preferred and dominant mode, where it is the fastest and most convenient for travelers." He offers little encouragement for extended or improved facilities to serve other parts of the metropolitan area, except those parts where plans are made "for clusters of sites of heavy employment within small enough areas so that most employees would be within easy walking distance from mass-transit stops to their places of employment." Surely there are plenty of such clusters on the New York side of the river. If the author is referring to clusters on New Jersey sites, the workers therein will undoubtedly choose to live in New Jersey and their home-to-work movements will not enter into the trans-Hudson statistics. The commuter railroads centering on the metropolitan hub are not laid out to serve such intra-suburban traffic and probably cannot compete with buses and private cars in that field. When one considers the commuters, the great proportion live in the suburbs and work in the central city and it is therefore clusters of suburban homes and not clusters of suburban industries that will justify mass transit to the metropolitan hub. At the rate the inner suburban areas are filling up with dense residential development, there is bound to be plenty of concentration to justify use of rail mass transit if an attractive and convenient service is provided.

(e) It was recommended that "A suburban transit connection between New Jersey and southern Manhattan, with stations convenient to all main business centers in the latter and fed by suburban railroad and bus lines in New Jersey, offers the ideal solution to the commuting problem. This would leave fixed vehicle crossings (other than ferries) of the Hudson River available for their most effective use, that is, general passenger and commercial travel throughout the day." This went back to the 1926 proposals of the North Jersey Transit Commission which were carried on in later studies by the Suburban Transit Engineering Board, the Committee on Regional Plan of New York and Its Environs (in its Graphic Regional Plan, where the New Jersey connection was also tied in with Long Island and Westchester County), the Port of New York Authority, the Regional Plan Association, and, more recently, the Bi-State Metropolitan Rapid Transit Commission (the "Page" Report).

Before presenting the writer's views on future trends and needs, some detailed comments on certain statements in Mr. Cherniack's paper may be in order.

In his sixth conclusion, drawn from his statistical study of the post-war decade, he finds that rail mass-transit across the Hudson River is today slower and more inconvenient than formerly. This is undoubtedly true, but need it continue to be so? The writer believes it possible to provide faster, more comfortable, and more convenient rail transit if only some of the existing political and financial roadblocks can be eliminated.

The author states that the vehicles that handle various types of transportation movements constitute the traffic flows. It is important to remember that the types of traffic flows with which we are most concerned in transportation planning are the people and goods which are moved and not the vehicles within which they are carried. Mr. Cherniack has also brought up this point.

In discussing Figs. 1 and 2 it would be well to point out that the increase in trans-Hudson railroad passengers during World War II was in non-commuter traffic and not in commuters, probably due to a switch from auto to rail as a result of the difficulty of obtaining gasoline rations except for essential workday travel. These two figures show that shortly after the War was ended auto traffic regained its former volume and then continued to increase, both numerically and relatively. The bus held its war-time gain, with only moderate increases in the 1950's.

In commenting on the behavior of mass-transit passengers across the Hudson River, Mr. Cherniack states that "planners would, therefore, do well to heed the desires of plannees as manifested by their deeds." The writer questions whether a switch of such travelers to other than rail facilities necessarily means that they prefer other types, or may have resulted only as a revolt against the inconvenience of rail transit as now operated. Would not better rail facilities or better operation thereof change their choice? It would be of interest if the paper had included statistics as to how many trans-Hudson riders already use two or more types of vehicles in their overall trip.

In discussing "reverse travel" Mr. Cherniack refers to the difficulty of scheduling such travel over railroads. Such movement may, however, greatly favor the railroads as it makes possible a pay-load in each direction, particularly if the New Jersey trains could run through to the Borough of Queens and pick up Long Island traffic on their return trip, and Long Island trains could run through to the edges of the Hackensack meadows to pick up New Jersey traffic on their return trip. Mr. Cherniack assumes that the morning and afternoon rush hours are each of three-hour duration. Surely there is time within this period to work out practical train schedules for such reverse movement as described above.

The future cannot be determined by a study of statistics only, so it is necessary to supplement such projections by the best opinions available. There is no dearth of support for a physical plan that would provide some sort of a railroad loop between New Jersey railroads and Manhattan, as shown by the plotting in Fig. 1 of six such proposals advanced during the 35 years, (since 1925). These all include a new Hudson River crossing to the midtown area of Manhattan and five of the six would use another new crossing near the "Battery." There must be merit in an interstate loop if the proposal is so persistent!

It is, generally, admitted that the obstacles have been financial and political. If it were not for that state line down the center of the Hudson River, the New York City rapid transit system would long ago have crossed that barrier as it has crossed the East River.

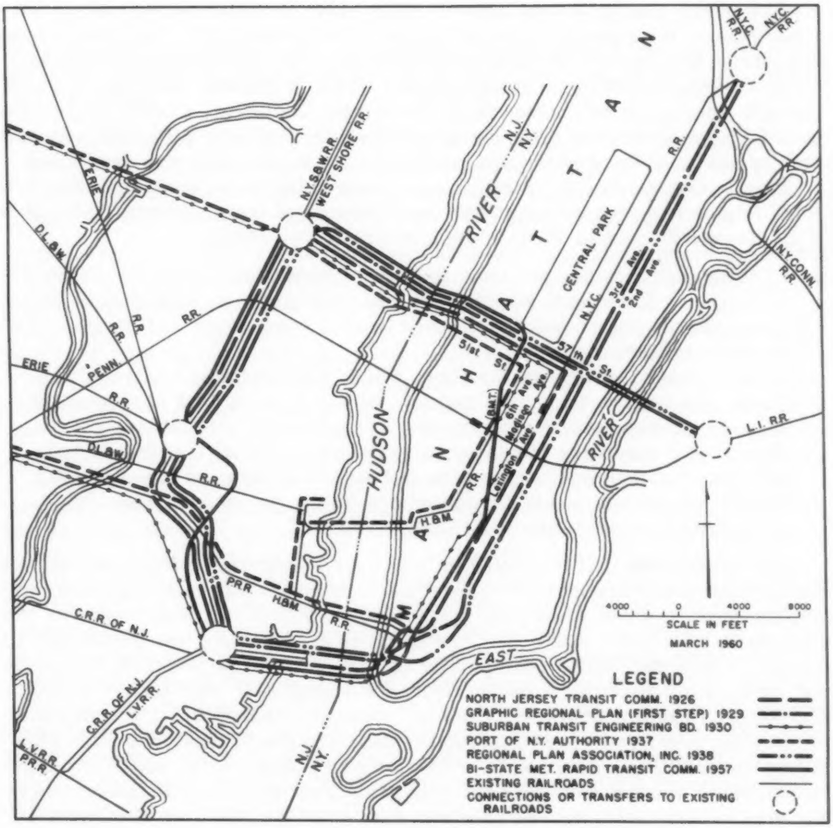


FIG. 1.—ALTERNATIVE PROPOSALS FOR N. J.-N. Y. SUBURBAN RAPID TRANSIT LOOP

In 1927, the Regional Survey of New York and Its Environs submitted to the New York Transit Commission a study[10] for such suggestions, to start with an extension of the 14th Street subway in Manhattan to the Meadows Transfer in New Jersey proposed by the North Jersey Transit Commission, and an extension of the Fourth Avenue subway in Brooklyn to Staten Island via the Narrows Tunnel (then partly constructed but later abandoned). The New Jersey connection was again advanced by the Regional Plan Association in 1954.[11]

At the time of the original suggestions, the city fathers were hesitant lest, through coming under control of the Interstate Commerce Commission, they would lose control over their rates and the five-cent fare. But the five-cent fare is now something in the dim past so far as most riders are concerned.

The immediate danger of commuter trains going out of service in the New York Region is a real threat. This was recognized in an editorial in the New York Herald Tribune of April 5, 1960, where it was stated:

> "Now, as every one has been saying for years, this cannot be allowed to happen. The result would be chaos. Certainly a large part of the metropolitan region would suffer in traffic congestion and decline of property values.
>
> "The crisis, of course, has been a long time building. All the emphasis has been put on providing for the automobile, and consequently the overtaxed and overregulated railroads have steadily lost out. Yet the most ardent advocates of rubber-age civilization insist that the ultimate collapse of commuter rail service is intolerable because buses and the private automobile would be inadequate to the job of providing rapid, comfortable, twice-a-day mass transportation."

The writer feels that the pendulum may have swung too far from rail to rubber and that the future may see a return to a more normal ratio. Los Angeles, Philadelphia, and San Francisco seem convinced that rail systems offer the only happy solution. While San Francisco is investigating the possibility of adding rails to the Golden Gate Bridge, the planned rail facilities in the original design for a lower deck on the George Washington Bridge across the Hudson River are in process of being replaced by new roadways, that will probably be crowded with buses whose passengers must transfer to rapid transit in Manhattan to reach their destination. Yet there are no plans for additional rapid transit lines, according to the Chairman of the New York City Transit Authority, who, in addressing the Metropolitan Section of the ASCE, on December 16, 1959, said that even a Second Avenue Subway, for which New York City taxpayers approved a bond issue (already spent for other purposes), has been completely dropped from their program. If this is so, why not utilize that route for suburban rapid transit as proposed by the Regional Plan Association, in 1938, (see Fig. 1)?

Highway engineers have recently predicted that expressways and automobiles of the future may provide that, on entering such a route, the driver can switch on to "automatic control," which will regulate not only his direction and his speed, but also his spacing from the car ahead and switch him off onto the exit road he may select. This would provide for the automobile a service comparable to the piggy-back container in which l.c.l. freight is handled by the rail-

---

10 "Transit and Transportation," Regional Survey of New York and Its Environs, Vol. IV, 1928, pp. 188-198.

11 Regional Plan News, No. 43, September, 1954, p. 2.

roads, and permit real door-to-door riding. This is an interesting development to contemplate, but the writer believes that in the largest metropolitan areas, and particularly in New York, rails must be the primary type of facility for access to a healthy metropolitan hub.

WILLIAM H. CLAIRE,[12] F. ASCE.—Mr. Cherniack has "put his finger" on one of the greatest opportunities, overlooked daily by most of our large cities, when he states

> "If communities wish to take advantage of the economies of existing mass transit on rails, where there is already sunk capital, they should encourage redevelopment of sites of employment in areas where the existing mass transit would be more attractive than the automobile."

There are two types of opportunities that we can take advantage of here. The one described by the author concerns existing transit facilities and the other involves proposed transit facilities.

Most existing rapid mass transit lines have been in existence for many years, as well as the development along each route, particularly at or near transit stations. Usually this development is obsolete and substandard and needs redevelopment through the coordinated efforts of private enterprise and government to replace the substandard conditions with modern improvements, such as apartment buildings, shopping centers and other facilities in demand in urban areas. The benefits from this type of urban renewal are legion—maximize the use of the existing transit facility and help put it on a paying basis, increase the tax base of the city, enhance city living convenience, reduce cost of city services, decrease amount of street traffic, just to mention a few.

Another opportunity with even greater economic return is redevelopment in the vicinity of transit stations on proposed mass rapid transit lines.[13] In this case, the land values would be considerably less than along existing routes and the public would, generally, realize the benefit of land-value-appreciation as a result of the transit facility. Also, the economic justification of the first cost of the transit facility would be materially bolstered by high-density planned residential and commercial development along the transit route and the resulting thousands of transit patrons provided thereby. Los Angeles, California, has this opportunity now, and the city could take advantage of it before the chance is lost.

---

[12] Urban Renewal and Planning Consultant, Pasadena, Calif. and Chmn., Committee on Urban Renewal, City Planning Div., ASCE.

[13] <u>Proceedings</u>, ASCE, Paper No. 964, May, 1956.

SPACING OF INTERCHANGES ON FREEWAYS IN URBAN AREAS[a]

Discussion by Gerald D. Love

GERALD D. LOVE,[1] A. M. ASCE.—The spacing of interchanges on freeways is one of the most important aspects of urban freeway design. As Mr. Leisch so ably points out, traffic service tends to be reduced when the spacing becomes too great and when too many interchanges are provided, the operational efficiency of the freeway itself is compromised. These two features, traffic service and operational characteristics, establish the limits of maximum and minimum interchange spacings.

The need for weaving sections of certain lengths between successive interchanges to satisfy traffic operational requirements, represents a valid approach to the determination of minimum interchange spacings. Mr. Leisch's "Design Chart For Spacing of Interchanges" has been developed on this basis. The two related variables of traffic flow, speed and volume, determine the required length of weaving sections. Thus, a weaving section of a certain length can accommodate different volumes of traffic if the speed is varied. This basic speed-volume information is essential in relating the operation of weaving sections to the overall operational characteristics of the freeway. Although Mr. Leisch makes reference to the fact that curve "C," which is labeled "low minimum spacing," is based on an average running speed of 35 mph, there is no indication as to the operating speed associated with curve "B." The design chart, presented as Fig. 3, would be more useful if the curves were developed for various operating speeds in lieu of curves labeled with such descriptive phraseology as low minimum, high minimum, and desirable. Any series of curves developed for interchange spacing would be essentially the same type as the weaving section curves presented in the Highway Capacity Manual.

Normally, weaving sections for collector-distributor roads are designed on the basis of a somewhat lower operating speed than weaving sections forming an integral part of the freeway. This aspect is brought out by Mr. Leisch in his proposal to utilize C-D roads as a method by which the frequency of connecting ramps may be increased. The use of the design chart would, thus, tend to provide a very liberal design. It does not appear that curve "C" represents a realistic minimum for determining interchange spacings involving collector-distributor roads.

Some interesting arrangements for permitting closer than so-called minimum spacing of ramps have been presented. As the author points out, the traffic demand for ingress and egress in some instances is of such magnitude that, if fully accommodated, the free flowing characteristics of a freeway would be destroyed by spacing ramps too closely. There are certain advantages to be

---

[a] December, 1959, by Jack E. Leisch.

[1] Highway Engr., U. S. Bur. of Pub. Rds., Albany, N. Y.

gained by the use of C-D roads and criss-cross ramps. Their use, however, as a means of permitting closer spacing of interchanges, per se, is a moot question. Although certain operational advantages can be gained by various ramp arrangements, ramp capacities are dependent, to an important degree, on the volume of traffic on the freeway. Increasing the ramp frequency may result in an unbalanced design. By providing a large number of points of ingress and egress, there is a greater possibility that the freeway will break down as a result of the previously mentioned critical traffic densities. In some instances this difficulty might be overcome by increasing the capacity of the freeway by added lanes but, as pointed out by Mr. Leisch, there is a practical limit to the number of lanes that can be provided so this solution can seldom be applied. It would seem that the primary consideration in determining the number of points of ingress and egress in areas of concentrated urban development would be that of a balanced design whereby a sufficient number of ramps are provided to permit the freeway to operate at practical capacity. With this basic design approach, ramp capacities are brought into balance with the capacity of the freeway, thus, preventing breakdowns of urban expressways because of overload. Traffic patterns, of course, must be considered to establish the inter-relationship of through freeway traffic and traffic volumes entering and exiting from the various ramps.

Although lateral distributors may be very effective in collecting and distributing traffic, the utilization of this type of design as an arrangement to increase the frequency of ramps is questioned. The spacing that is being considered is the interchange or ramp spacing along the freeway. The same design criteria (minimum weaving distance requirements) control the spacing of lateral distributors shown in Fig. 5(g) as in the conventional layout shown in Fig. 5(a). Apparently, the author derived the spacing index of 2.0 for the lateral distributors by some other means.

Mr. Leisch's concept of providing C-D roads continuously on all or parts of inner loop highways between major interchanges provides a means of removing weaving maneuvers from the through lanes. A diagrammatic sketch of an inner circumferential highway was presented as Fig. 7. Some of the major disadvantages of this proposal may be visualized by referring to this sketch. Multi-level interchanges are shown at the two intersections of the freeway and the distributors. Interchanges of this type require considerable right-of-way, which is very costly in downtown areas. The problems associated with obtaining satisfactory grades and the elimination of the existing surface streets in the interchange areas are of major concern. To maintain the continuity of the existing street network it would be necessary to either elevate or depress the freeway and C-D roads. Although weaving movements can be removed from the freeway by providing continuous C-D roads, the heavy weaving volumes on the C-D roads would still be a major problem. The construction of a total of 12 or 14 lanes on four traveled ways with provisions for ramp connections between parallel roadways would require an extremely wide right-of-way. These features have been presented to support the point that freeways with more than 6 or 8 lanes in areas of concentrated urban development involve designs of doubtful practicability from both an engineering and economic viewpoint. The resulting heavy concentration of traffic may also lead to serious difficulties.

What other means or types of designs, then, may provide a solution to the movement of heavy traffic flows in downtown areas? If at all possible we

should avoid an extreme concentration of traffic on one facility with the resulting interchange and distribution problems. Approximately 30% of downtown areas are occupied by streets and parking areas. Even at the time of peak hour flows the potential street capacity is not fully utilized in our large metropolitan cities. Although traffic destinations may be concentrated in the CBD, there are many streets in this area to absorb the demand.

A logical approach to the problem would be to increase the capacity of the existing facilities by means of traffic control devices, one-way streets, the elimination of parking, at least during peak hour flows, and the construction of additional at-grade expressways. Freeways and inner circumferentials should, of course, be considered as an integral part of an over-all city highway improvement program but the number of lanes could be limited to six or eight if additional capacity could be obtained by improving the existing surface street network.

It would seem that in some instances, multi-lane freeways have been proposed as a solution to the growing traffic problems in our large urban areas. Certainly, freeways have a definite function but the over-all traffic problem cannot be solved by freeways alone. Better utilization of our existing street networks must be considered in meeting our growing traffic demands.

Mr. Leisch has presented a very interesting paper on a subject of utmost importance. The problem of properly serving the traffic demands of downtown areas should receive the cooperative attention of city and state representatives.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 2270 is identified as 2270(ST9) which indicates that the paper is contained in the ninth issue of the Journal of the Structural Division during 1959.

VOLUME 85 (1959)

JUNE: 2048(CP1), 2049(CP1), 2050(CP1), 2051(CP1), 2052(CP1), 2053(CP1), 2054(CP1), 2055(CP1), 2056 (HY6), 2057(HY6), 2058(HY6), 2059(IR2), 2060(IR2), 2061(PO3), 2062(SM3), 2063(SM3), 2064(SM3), 2065 (ST6), 2066(WW2), 2067(WW2), 2068(WW2), 2069(WW2), 2070(WW2), 2071(WW2), 2072(CP1)c, 2073(IR2)c, 2074(PO3)c, 2075(ST6)c, 2076(HY6)c, 2077(SM3)c, 2078(WW2)c.

JULY: 2079(HY7), 2080(HY7), 2081(HY7), 2082(HY7), 2083(HY7), 2084(HY7), 2085(HY7), 2086(SA4), 2087 (SA4), 2088(SA4), 2089(SA4), 2090(SA4), 2091(EM3), 2092(EM3), 2093(EM3), 2094(EM3), 2095(EM3), 2096 (EM3), 2097(HY7)c, 2098(SA4)c, 2099(EM3)c, 2100(AT3), 2101(AT3), 2102(AT3), 2103(AT3), 2104(AT3), 2105(AT3), 2106(AT3), 2107(AT3), 2108(AT3), 2109(AT3), 2110(AT3), 2111(AT3), 2112(AT3), 2113(AT3), 2114(AT3), 2115(AT3), 2116(AT3), 2117(AT3), 2118(AT3), 2119(AT3), 2120(AT3), 2121(AT3), 2122(AT3), 2123(AT3), 2124(AT3), 2125(AT3).

AUGUST: 2126(HY8), 2127(HY8), 2128(HY8), 2129(HY8), 2130(PO4), 2131(PO4), 2132(PO4), 2133(PO4), 2134 (SM4), 2135(SM4), 2136(SM4), 2137(SM4), 2138(HY8)c, 2139(PO4)c 2140(SM4)c.

SEPTEMBER: 2141(CO2), 2142(CO2), 2143(CO2), 2144(HW3), 2145(HW3), 2146(HW3), 2147(HY9), 2148(HY9), 2149(HY9), 2150(HY9), 2151(IR3), 2152(ST7)c, 2153(IR3), 2154(IR3), 2155(IR3), 2156(IR3), 2157(IR3), 2158 (IR3), 2159(IR3), 2160(IR3), 2161(SA5), 2162(SA5), 2163(ST7), 2164(ST7), 2165(SU1), 2166(SU1), 2167(WW3), 2168(WW3), 2169(WW3), 2170(WW3), 2171(WW3), 2172(WW3), 2173(WW3), 2174(WW3), 2175(WW3), 2176 (WW3), 2177(WW3), 2178(CO2)c, 2179(IR3)c, 2180(HW3)c, 2181(SA5)c, 2182(HY9)c, 2183(SU1)c, 2184 (WW3)c, 2185(PP2)c, 2186(ST7)c, 2187(PP2), 2188(PP2).

OCTOBER: 2189(AT4), 2190(AT4), 2191(AT4), 2192(AT4), 2193(AT4), 2194(EM4), 2195(EM4), 2196(EM4), 2197(EM4), 2198(EM4), 2199(EM4), 2200(HY10), 2201(HY10), 2202(HY10), 2203(PL3), 2204(PL3), 2205 (PL3), 2206(PO5), 2207(PO5), 2208(PO5), 2209(PO5), 2210(SM5), 2211(SM5), 2212(SM5), 2213(SM5), 2214 (SM5), 2215(SM5), 2216(SM5), 2217(SM5), 2218(ST8), 2219(ST8), 2220(EM4), 2221(ST8), 2222(ST8), 2223 (ST8), 2224(HY10), 2225(HY10), 2226(PO5), 2227(PO5), 2228(PO5), 2229(ST8), 2230(EM4), 2231(EM4), 2232(AT4)c, 2233(PL3)c, 2234(EM4)c, 2235(HY10)c, 2236(SM5)c, 2237(ST8)c, 2238(PO5)c, 2239(ST8), 2240 (PL3).

NOVEMBER: 2241(HY11), 2242(HY11), 2243(HY11), 2244(HY11), 2245(HY11), 2246(SA6), 2247(SA6), 2248 (SA6), 2249(SA6), 2250(SA6), 2251(SA6), 2252(SA6), 2253(SA6), 2254(SA6), 2255(SA6), 2256(ST9), 2257(ST9), 2258(ST9), 2259(ST9), 2260(HY11), 2261(ST9)c, 2262(ST9), 2263(HY11), 2264(ST9), 2265(HY11), 2266(SA6), 2267(SA6), 2268(SA6), 2269(HY11)c, 2270(ST9).

DECEMBER: 2271(HY12)c, 2272(CP2), 2273(HW4), 2274(HW4), 2275(HW4), 2276(HW4), 2277(HW4), 2278 (HW4), 2279(HW4), 2280(HW4), 2281(IR4), 2282(IR4), 2283(IR4), 2284(IR4), 2285(PO6), 2286(PO6), 2287 (PO6), 2288(PO6), 2289(PO6), 2290(PO6), 2291(PO6), 2292(SM6), 2293(SM6), 2294(SM6), 2295(SM6), 2296 (SM6), 2297(WW4), 2298(WW4), 2299(WW4), 2300(WW4), 2301(WW4), 2302(WW4), 2303(WW4), 2304(HW4), 2305(ST10), 2306(CP2), 2307(CP2), 2308(ST10), 2309(CP2), 2310(HY12), 2311(HY12), 2312(PO6), 2313(PO6), 2314(ST10), 2315(HY12), 2316(HY12), 2317(HY12), 2318(WW4), 2319(SM6), 2320(SM6), 2321(ST10), 2322 (ST10), 2323(HW4)c, 2324(CP2)c, 2325(SM6)c, 2326(WW4)c, 2327(IR4)c, 2328(PO6)c, 2329(ST10)c, 2330 (CP2).

VOLUME 86 (1960)

JANUARY: 2331(EM1), 2332(EM1), 2333(EM1), 2334(EM1), 2335(HY1), 2336(HY1), 2337(EM1), 2338(EM1), 2339(HY1), 2340(HY1), 2341(SA1), 2342(EM1), 2343(SA1), 2344(ST1), 2345(ST1), 2346(ST1), 2347(ST1), 2348(EM1)c, 2349(HY1)c, 2350(ST1), 2351(ST1), 2352(SA1)c, 2353(ST1)c, 2354(ST1).

FEBRUARY: 2355(CO1), 2356(CO1), 2357(CO1), 2358(CO1), 2359(CO1), 2360(CO1), 2361(PO1), 2362(HY2), 2363(ST2), 2364(HY2), 2365(SU1), 2366(HY2), 2367(SU1), 2368(SM1), 2369(HY2), 2370(SU1), 2371(HY2), 2372(PO1), 2373(SM1), 2374(HY2), 2375(PO1), 2376(HY2), 2377(CO1)c, 2378(SU1), 2379(SU1), 2380(SU1), 2381(HY2)c, 2382(ST2), 2383(SU1), 2384(ST2), 2385(SU1)c, 2386(SU1), 2387(SU1), 2388(SU1), 2389(SM1), 2390(ST2)c, 2391(SM1)c, 2392(PO1)c.

MARCH: 2393(IR1), 2394(IR1), 2395(IR1), 2396(IR1), 2397(IR1), 2398(IR1), 2399(IR1), 2400(IR1), 2401(IR1), 2402(IR1), 2403(IR1), 2404(IR1), 2405(IR1), 2406(IR1), 2407(SA2), 2408(SA2), 2409(HY3), 2410(ST3), 2411 (SA2), 2412(HW1), 2413(WW1), 2414(WW1), 2415(HY3), 2416(HW1), 2417(HW3), 2418(HW1)c, 2419(WW1)c, 2420(WW1), 2421(WW1), 2422(WW1), 2423(WW1), 2424(SA2), 2425(SA2)c, 2426(HY3)c, 2427(ST3)c.

APRIL: 2428(ST4), 2429(HY4), 2430(PO2), 2431(SM2), 2432(PO2), 2433(ST4), 2434(EM2), 2435(PO2), 2436 (ST4), 2437(ST4), 2438(HY4), 2439(EM2), 2440(EM2), 2441(ST4), 2442(SM2), 2443(HY4), 2444(ST4), 2445 (EM2), 2446(ST4), 2447(EM2), 2448(SM2), 2449(HY4), 2450(ST4), 2451(HY4), 2452(HY4), 2453(EM2), 2454 (EM2), 2455(EM2)c, 2456(HY4)c, 2457(PO2)c, 2458(ST4)c, 2459(SM2)c.

MAY: 2460(AT1), 2461(ST5), 2462(AT1), 2463(AT1), 2464(CP1), 2465(CP1), 2466(AT1), 2467(AT1), 2468(SA3), 2469(HY5), 2470(ST5), 2471(SA3), 2472(SA3), 2473(ST5), 2474(SA3), 2475(ST5), 2476(SA3), 2477(ST5), 2478 (HY5), 2479(SA3), 2480(ST5), 2481(SA3), 2482(CO2), 2483(CO2), 2484(HY5), 2485(HY5), 2486(AT1)c, 2487 (CP1)c, 2488(CO2)c, 2489(HY5)c, 2490(SA3)c, 2491(ST5)c, 2492(CP1), 2493(CO2).

JUNE: 2494(IR2), 2495(IR2), 2496(ST6), 2497(EM3), 2498(EM3), 2499(EM3), 2500(EM3), 2501(SM3), 2502 (EM3), 2503(PO3), 2504(WW2), 2505(EM3), 2506(HY6), 2507(WW2), 2508(PO3), 2509(ST6), 2510(EM3), 2511 (EM3), 2512(ST6), 2513(HW2), 2514(HY6), 2515(PO3), 2516(EM3), 2517(WW2), 2518(WW2), 2519(EM3), 2520 (PO3), 2521(HY6), 2522(SM3), 2523(ST6), 2524(HY6), 2525(HY6), 2526(HY6), 2527(IR2), 2528(ST6), 2529 (HW2), 2530(IR2), 2531(HY6), 2532(EM3)c, 2533(HW2)c, 2534(WW2), 2535(HY6)c, 2536(IR2)c, 2537(PO3)c, 2538(SM3)c, 2539(ST6)c, 2540(WW2)c.

c. Discussion of several papers, grouped by divisions.

AMERICAN SOCIETY OF CIVIL ENGINEERS

OFFICERS FOR 1960

PRESIDENT

FRANK A. MARSTON

VICE-PRESIDENTS

Term expires October, 1960:
PAUL L. HOLLAND
LLOYD D. KNAPP

Term expires October, 1961:
CHARLES B. MOLINEAUX
LAWRENCE A. ELSENER

DIRECTORS

Term expires October, 1960:
PHILIP C. RUTLEDGE
WESTON S. EVANS
TILTON E. SHELBURNE
CRAIG P. HAZELET
DONALD H. MATTERN
JOHN E. RINNE

Term expires October, 1961:
THOMAS J. FRATAR
EARL F. O'BRIEN
DANIEL B. VENTRES
CHARLES W. BRITZIUS
WAYNE G. O'HARRA
FRED H. RHODES, JR.
N. T. VEATCH

Term expires October, 1962:
ELMER K. TIMBY
SAMUEL S. BAXTER
THOMAS M. NILES
TRENT R. DAMES
WOODROW W. BAKER
BERNHARD DORNBLATT

PAST PRESIDENTS
Members of the Board

LOUIS R. HOWSON

FRANCIS S. FRIEL

EXECUTIVE SECRETARY
WILLIAM H. WISELY

TREASURER
E. LAWRENCE CHANDLER

ASSISTANT TREASURER
ENOCH R. NEEDLES

PROCEEDINGS OF THE SOCIETY

HAROLD T. LARSEN
Manager of Technical Publications

PAUL A. PARISI
Editor of Technical Publications

MARVIN L. SCHECHTER
Associate Editor of Technical Publications

IRVIN J. SCHWARTZ
Assistant Editor of Technical Publications

COMMITTEE ON PUBLICATIONS

PHILIP C. RUTLEDGE, *Chairman*

THOMAS M. NILES, *Vice-Chairman*

TILTON E. SHELBURNE

WAYNE G. O'HARRA

WESTON S. EVANS

BERNHARD DORNBLATT

PART 2

JUNE 1960 — 18
VOLUME 86

NO. HW 2
PART 2

Your attention is invited

NEWS OF THE HIGHWAY DIVISION OF ASCE

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

JOURNAL OF THE HIGHWAY DIVISION
PROCEEDINGS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

DIVISION ACTIVITIES
HIGHWAY DIVISION
Proceedings of the American Society of Civil Engineers

NEWS

June, 1960

IN REBUTTAL

Attention: Highway Division

Re: "An Answer to Criticism" in the News of December, 1959

"Gentlemen:

Mr. Morton, Chairman of the Executive Committee is to be commended for his defense of the designers and planners of our highway systems, both urban and rural. However, it is hoped that his response to criticism does not constitute a blanket endorsement of the judgment used by highway planners (both in government service and in private practice) in their operations throughout the length and breadth of our country. Given a set of conditions, the planners apparently do an excellent job in the design of any given highway. However, the judgment exercised in establishing those conditions must always be open to most careful scrutiny, because actually relatively little is known of the total and final effect of the establishment of urban freeways in particular.

Much criticism has already been leveled at the wisdom of a fair percentage of the judgment shown in planning highways in metropolitan areas. It is often felt that too little consideration has been given to the social impact of new locations involving radical changes in neighborhoods, neighborhood services and previous planning done by established planning departments, school departments and park departments. An essential part of the approach to solutions of highway location and design is a constant attitude of openminded inquiry, a continual criticism of each solution and a fair and impartial evaluation after such projects are completed.

We must constantly remind ourselves that the introduction of urban freeways into the very heart of metropolitan areas is of such a recent origin and has such far-reaching effect in many aspects of urban life other than engineering, that not much more than a "scratching of the surface" has been accomplished in determining satisfactory theories underlying location, appearance, social impact and even construction standards. The public clamors for more and better highways. Huge sums are appropriated to pay the cost. The engineers are looked to, to provide all the answers. Power and urgency may

Note.—No. 1960-18 is part of the copyrighted Journal of the Highway Division, Proceedings of the American Society of Civil Engineers, Vol. 86, No. HW 2, June, 1960.

lead engineers to believe they can provide all the answers. They can't. Hence their works will be subject to criticism.

Engineers should not be maligned for doing their best (which may be better than any other profession can do), but they should be willing to accept good constructive criticism.

Very truly yours,

Charles E. Doell
Superintendent of Parks Emeritus
Minneapolis, Minnesota
Fellow, A.S.C.E."

EXECUTIVE COMMITTEE MEETING - NEW ORLEANS CONVENTION

Committee on Highway Transportation Policy

The organization of the Committee on Highway Transportation Policy has been completed. Members are: Harmer E. Davis (Chairman), Carl E. Fritts, Robert G. Hennes, Frank W. Herring, Bertram H. Lindman, John Logan, and Frank C. Turner.

Contact With Technical Committees

It was the consensus of the Committee that there should be more direct contact between the Executive Committee and the Technical Committees, especially at regional and annual meetings.

Next Meeting

The next Executive Committee Meeting will be held in Boston in October, 1960.

Committee Discussion

The committee discussed the broadened scope of interest in highway affairs, the overlapping responsibilities of highway officials, state, county, city and traffic engineers, highway and city planners, transit and terminal authorities, etc. Specific to the discussion were past attempts to establish forums where these overlapping and often diverse interests could be brought together for better understanding. Particularly, the Hartford and Sagamore Conferences were discussed. There was strong feeling in the committee that ASCE, particularly the Highway Division, had responsibility and could play an important part in resolving the diversity of interests which now exist.

Resolution

The following resolution was unanimously approved:

WHEREAS, the Executive Committee of the Highway Division, in meeting in New Orleans, March 8, 1960, has thoroughly and considerately discussed the suggestion for creation, within the Society, of a division on mass transportation, contained in a letter to the Executive Committee from Don Reynolds dated October 30, 1959; and

WHEREAS, it is the consensus of the Executive Committee that mass transportation is a subject so closely allied to highways that it could not, from the viewpoint of civil engineering, stand alone; and

WHEREAS, it is the considered opinion of the Executive Committee that the subject of mass transportation can best be served by expanded activities of existing divisions and technical committees;

THEREFORE, BE IT RESOLVED, That the Executive Committee unanimously urges against the creation of a new division on mass transportation.

Proposed Committees on Terminals and Mass Transit

A suggestion of Harmer Davis regarding the creation of a technical committee on terminals was discussed. It was the consensus that not only a committee on this topic was needed but also one on the highway engineering aspects of mass transit.

It was unanimously agreed that the secretary invite Mr. Edward G. Wetzel to set up a task committee to define the scope and purpose of a committee on terminals and that Mr. William R. Mc Conochie be invited to do the same thing for a committee on highway engineering aspects of mass transit.

Letter of Appreciation Regarding New Orleans Meeting

The committee directed the secretary to write a letter of appreciation to Louis Duclos for the excellent program of highway sessions he arranged.

NORTHWESTERN FELLOWSHIPS OFFERED

Several Fellowships and Assistantships are available at Northwestern University for graduate study in transportation areas of Civil Engineering during 1960-61. These include:

1. A $3,000 Fellowship made available by the Automotive Safety Foundation for a graduate student majoring in urban transportation planning. This is a tax-free grant permitting the student to devote full time to academic studies and research. The student pays tuition ($240 per quarter).
2. Transportation Center Fellowships in amounts to $2,800.
3. Research Assistantships, paying $200 monthly plus tuition for 20 hours per week on sponsored research. Currently, there are three openings on two projects: (1) Lane Use Controls at Intersections; (2) Feasibility of Left-Hand On-and-Off Ramps.
4. Technological Institute Fellowships and Assistantships.

The graduate study program at Northwestern is under the direction of Professor Donald S. Berry, Department of Civil Engineering. For further information, address him at the Technological Institute, Northwestern University, Evanston, Illinois.

INTERSTATE HIGHWAYS IN HAWAII

In a report to Congress pursuant to Section 105 of the Federal-Aid Highway Act of 1959, Secretary of Commerce Frederick H. Mueller has recommended the allocation of 50 miles of the National System of Interstate and Defense Highways to Hawaii.

The inclusion of this mileage in Hawaii should be accommodated within the present 41,000-mile limitation on the Interstate System, and could be designated from mileage resulting from adoption of more direct locations of routes of the previously designated system, according to the report. All of the recommended mileage is on the island of Oahu.

BUREAU MANUAL SETS REFERENCE POINTS

An instruction manual recently issued by the Bureau of Public Roads to aid states in the preparation of revised estimates of the cost of completing the Interstate System establishes a number of guides for freeway design. The manual has been mistakenly interpreted by some as setting new design standards. This was not the purpose of the publication, according to officials of the Bureau, who point out that certain reference points are all that the manual establishes.

PERTINENT PUBLICATIONS

"A Framework for Urban Studies" - Special Report No. 52, Highway Research Board, 2101 Constitution Avenue, Washington 25 D. C. October 1959. 29 pp. $1.20.
This report reflects the current state of knowledge on research needs and priorities in this area.

"Trans-Hudson Vehicular Origin and Destination Survey" - Annual Report-1958. Port of New York Authority, 111 Eighth Avenue, New York 11, New York, October 1959. 69 pp. appendices.
The "continuous sampling" techniques developed by the Port Authority, previously reported in tentative form, are here applied to a full year of operations.

"De Schoonheid van de Weg (The Beauty of the Road)" - Het Nederlandsche Wegen - Congres, Nassaplein 12, Gravenhage, Netherlands. 1959. 75 pp., plus appendices containing an English translation. Price, fl.10.
A picture book on the aesthetic aspects of road design. The compilers point out that a pleasant, attractive and restful road may be a more efficient road, and that designing good roads is a technical scientific and artistic endeavor. Although all picture captions are in Flemish, an appendix provides English, German and French translations.

"Studies of the Central Business District and Urban Freeway Development" - Edgar M. Horwood and Ronald R. Boyce. University of Washington Press, Seattle 5, Washington. 1959. 200 pp., bibliography, index. $5.00.
These studies examine the changing structure of the central business district (CBD) and seek to evaluate this change in relation to burgeoning urban highway networks.

"Studies of Highway Development and Geographic Change" - William L. Garrison, Brian J. L. Berry, Duane F. Marble, and Richard L. Morrill. University of Washington Press, Seattle 5, Washington 1959. 310 pp., bibliography, index. $7.50.
What will be the effects of the accelerated development of highway facilities on retail businesses, residential areas, and service centers with their

associated trade areas? Who benefits from highway developments? How may these benefits be measured?

These questions are considered as part of the general problem of non-user benefits identified in the Highway Revenue Act of 1956.

"A Guide for the Geometric Layout of Interchanges" - Michigan State Highway Department, Lansing, Michigan, January 1960. 45 pp. (mimeo) plus bibliography.

Prepared as a guide for those responsible for the layout and design of interchanges in Michigan, this publication sets standards based on AASHO policies, defines limits when such policies allow some discretion, and in some cases defines situations which are not covered in the AASHO policy.

"Traffic Behavior on Freeways" - Bulletin 235, Highway Research Board, 2101 Constitution Avenue, Washington 25, D. C. January 1960. 132 pp. $2.40.

This bulletin contains four papers on this subject as presented at the 38th Annual Meeting of the Highway Research Board.

MEETING CALENDAR

ASCE MEETINGS - 1960

June 19-23	Reno Convention Contact: George Langsner Engineer of Design Division of Highways P. O. Box #1499 Sacramento 7, California
October 10-14	Boston Convention Contact: E. F. Copell Chief Engineer New England Division De Leuw, Cather &Company 361 Boyleston Street Brookline 46, Massachusetts
April 10-15	Phoenix Convention Contact: E. V. Miller Johanessen, Girard &Miller Phoenix, Arizona
June 8-11	National Society of Professional Engineers Annual Meeting Statler Hotel, Boston, Massachusetts Contact: K. E. Trombley N. S. P. E. 2029 K Street, N. W. Washington 6, D. C.

September 12-16

Institute of Traffic Engineers
30th Annual Meeting
Edgewater Beach Hotel
Chicago, Illinois
Contact: I. T. E.
2029 K Street, N. W.
Washington 6, D. C.

September 26-30

Fifth International Traffic Study Week
Nice, France
Contact: M. H. Perlowski
Secretary to the OTA/PIARC/IRF
Joint Committee
32 Chesham Place
London, S. W. 1, England

DEADLINE FOR SEPTEMBER 1960 NEWSLETTER

July 15, 1960

Send contributions to the Newsletter Editor:

EDMUND J. CANTILLI
Room 1202
The Port of New York Authority
111 Eighth Avenue
New York 11, New York